Assessing resilience in Collie

A case study in Western Australia

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Declaration

I declare that this is my own account of my research and has not been previously submitted for a degree at any university.

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Abstract

Resilience is a system's ability to absorb or adapt to change without losing essential structures and functions. In a changing world, resilience assessment is a means of assessing the condition of complex ecological and social systems in the face of multiple trends and threats. This thesis examines the usefulness of resilience assessment as a policy tool when applied to communities that will be affected by policies to reduce greenhouse gas emissions, via a case study of Collie, Western Australia. A historical analysis shows that Collie's coal industry is in the late conservation stage of an adaptive cycle and vulnerable to collapse. Current threats to the industry include climate change, greenhouse gas mitigation policies, competition from other energies, local air quality concerns, growing industrial demand for water and finite coal reserves. While some threats are volatile and therefore predictions are uncertain, these threats appear likely to push the industry into serious decline within the near to medium term (10–15 years). Collie has some capacity to adapt to such a transition, including moderate existing economic diversity and strong social capital but it appears that community awareness about the threats could be enhanced. In addition, there is evidence that perverse resilience influences energy policy in Western Australia, with persistent structures and functions that cause social and environmental harm. These are causing unequal flow of wealth and opportunity in Collie and are undermining its adaptive capacity. If new coal projects proceed, Collie will sacrifice important assets including water supplies, rivers, clean air, rural lifestyle, sense of place and heritage, along with future opportunities to diversify its economy. Alternatively, it could prepare now for inevitable transition. Resilience assessment is a useful tool for other communities that are likely to experience transition owing to climate change and resource depletion, including north-west WA towns that are also home to high greenhouse gas-intensity industries.

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Acronyms	
ABS	Australian Bureau of Statistics
BoM	Bureau of Meteorology
CCS	Carbon capture and storage
CO2e	Carbon dioxide equivalent (refers to all greenhouse gas emissions including carbon dioxide as well as other gases contributing to the Greenhouse Effect)
CPRS	Carbon Pollution Reduction Scheme
DEC	Department of Environment and Conservation Western Australia
DMP	Department of Mines and Petroleum Western Australia
DoCCEE	(Federal) Department of Climate Change and Energy Efficiency
DoH	Department of Health Western Australia
DoW	Department of Water Western Australia
DTF	Department of Treasury and Finance Western Australia
EPA	Environmental Protection Authority Western Australia
GCCSI	Global Carbon Capture and Storage Institute
IOCI	Indian Ocean Climate Initiative
IPCC	Intergovernmental Panel on Climate Change
LNG	liquefied natural gas
Mtpa	million tonnes per annum (of coal production, C02e emissions, LNG, etc.)
RAG	(Collie) Rural Action Group
SoC	Shire of Collie
SWDC	South West Development Commission
WPC	Wesfarmers Premier Coal

Chapter 1: Introduction

1.1 A resilience approach to sustainability

Resilience is an emerging concept in sustainability, defined as a system's capacity to absorb or adapt to change while retaining essential form and function (Walker & Salt, 2006; Resilience Alliance, 2010). Resilience thinking may be applied to both ecosystems and social systems. However, resilience writers recognise that most systems, such as a catchment, forest, town or industry, are influenced by both biophysical and human variables and thus can be considered social-ecological systems (Holling, 1973; 2001; Walker & Salt, 2006; Gallopin, 2007).

Resilience assessment is a way of thinking about the cross-scale influences upon complex social-ecological systems to help inform policy development. To date, resilience assessment has mostly been used in the field of natural resource management. This thesis examines the usefulness of resilience assessment for industries and communities facing transition due to greenhouse gas mitigation policies and other sustainability challenges.

1.2 A changing world

Resilience thinking recognises that complex social-ecological systems are typically in a state of transience, particularly in the current era of rapid human population growth and technological development, and the subsequent degradation and consumption of resources (Holling, 1973). Possibly the most pervasive of these changes is anthropogenic global warming, described by United Nations Secretary General Ban Ki-Moon (2007) as one of the most complex and serious threats the world faces. In south-west Western

Australia, man-made climate change has caused an average 0.8C temperature rise since 1910, a 20 per cent decline in rainfall and 40–50 per cent decline in dam inflows since the 1970s (Department of Climate Change and Energy Efficiency (DoCCEE), 2010). It has been blamed for declines in Western Australia's western rock lobster fishery and dairy industry, and is projected to slow future sheep, wheat and beef production (DoCCEE; Western Dairy, 2008). It is blamed for a 20cm sea level rise at Fremantle since 1897 and is projected to displace 29,000 Western Australian homes by 2100 (Indian Ocean Climate Initiative (IOCI), 2005; DoCCEE, 2010). It is likely to cause heat-related deaths in Wesern Australia to double to 670 annually by 2020, rising to 1,500 annually by 2050 (Department of Health Western Australia (DoH)) and will increase the spread of mosquito-born diseases, injury from fires and extreme weather events and poor water quality (DoH, 2008; DoCCEE, 2010). Scientists also warn climate change will cause major declines in biodiversity and affect the health of the State's landscape and inland and marine waters (Environmental Protection Authority Western Australia (EPA), 2007).

However, impacts in Western Australia are minor in comparison with much greater human suffering being caused by climate change in other parts of the world (Intergovernmental Panel on Climate Change (IPCC), 2007). Scientists such as Hansen (2008) warn that if greenhouse gas emissions are not curbed, tipping points will be passed, leading to even greater changes. This creates a moral imperative to try to reduce greenhouse gas emissions – and a dilemma for those entities that are high emitters.

Western Ausralia's greenhouse gas emissions amounted to 79.5 million tonnes in 2008 (Australian National Greenhouse Accounts (ANGA), 2010: 1), making the State one of the highest emitting regions per capita in the world. More than half of Western Australia's emissions (44mtpa) come from the stationary energy sector, including coal

and gas-fired electricity generation, as well as mineral processing, manufacturing and transport (ANGA, 2010: 6). Planned new gas and coal projects will double the State's total greenhouse gas emissions by around 2016 unless carbon capture and storage technology can be comprehensively implemented before then (Appendix 2). Meanwhile, Western Australia's population is projected to double from 2.1 million now to 4.3 million by 2056 (Australian Bureau of Statistics (ABS), 2008) and individual household energy consumption is increasing, adding to the rising demand for land, water and energy (EPA, 2007).

Should severe cuts in greenhouse gas emissions be required, the State's high-emitting industries will be forced to modify or replace existing infrastructure, or close (EPA, 2007). Closure will have major impacts on any communities whose economies are heavily reliant on these industries. There is therefore a need to assess the level of exposure of such communities to greenhouse gas reduction policies and how prepared they are to adapt to such changes. It would seem unwise to conduct such assessments in isolation from the other effects these industries have on the landscape and communities, or to overlook other pressures which threaten their viability, such as demand for water or land and the extent of the exploited resource. Peak oil, peak coal and peak gas are all relevant considerations for the future security of an energy-hungry economy such as Western Australia's.

1.3 Perverse resilience

Although the most credible evidence from climate scientists and leading economists is that large cuts in greenhouse gas emissions are required and are best introduced early rather than later (Stern, 2006; IPCC, 2007), Australia is yet to make such commitments. Rather than an application of the precautionary principle in response to uncertainty

about future climate scenarios, debate continues about whether climate change science is reliable. This inertia in the face of mounting evidence of the need to act arguably demonstrates perverse resilience; in other words, resistance to beneficial change despite current conditions causing human and/or ecological harm (Ráez-Luna, 2008; Evans, 2009; Albrecht, 2010). Given the current trajectory of emissions from fossil fuel industries in Australia, investigating perverse resilience is an important area of resilience research, and thus a secondary line of inquiry in this thesis.

1.4 Resilience research in Western Australia

Resilience-based approaches to assessing sustainability have been applied to Australian agricultural regions, catchment areas and bioregions.[1] Less common are resilience studies of industries and associated towns, although Evans' 2009 study of coalmining in New South Wales' Hunter Valley, building on work by Conner et al. (2004), Albrecht (2005) and Higginbotham et al. (2010), is a clear exception. Evans uses a resilience framework to examine the influence of power, politics and perverse resilience in the Hunter Valley and his research provides useful insights for this thesis.

A search for resilience assessments of resource-extraction industries or associated communities in Western Australia produced no result, but Haslam-McKenzie (2009) has made a useful comparison of two Western Australian towns in transition, Manjimup and Exmouth, while Newman et al. (2010) have investigated sustainability options for the Pilbara. A search for any form of sustainability assessment of Collie, Western Australia's only coalmining community, also produced nil result. However, there have

[1] For example, Goulburn-Broken Catchment in south-eastern Australia (Walker et al., 2009); the Western Australian Wheatbelt (Allison & Hobbs, 2004); and New South Wales Rangelands ('Case Studies', Resilience Alliance, 2010).

been calls for such work: Greens Party politicians and environmentalists have called for vulnerability assessments and 'just transition' planning for communities involved in high greenhouse gas-emitting industry, including Collie (Ludlam, 2009; Climate Camp WA, 2009). A University of Newcastle study investigated wind and solar power generation as alternative industries to coal in the Hunter Valley, showing that this could be done without economic restructuring costs falling on workers (Bill et al., 2008). The need for just transition planning for vulnerable workers (and by implication, the communities they come from) was also referenced by Evans (2009) and in the international discussions leading up to the UN Climate Change Conference in Copenhagen in December 2009 (UN Framework Convention on Climate Change, 2009).

1.5 Research aims

The primary role of this thesis is to explore the usefulness of resilience assessment as a planning tool for communities who may be exposed by policies to reduce greenhouse gas emissions. In order to satisfy this guiding aim, this thesis will:

1. Explore resilience theory as an approach to sustainability assessment, including differences between social and ecological systems.

2. Investigate the resilience of a community reliant on a greenhouse gas-intense industry: Collie, Western Australia, including an examination of Collie's history, looming major threats to the coal industry and Collie's capacity to adapt to these threats.

3. Consider the role of perverse resilience in relation to Collie.

4. Consider whether resilience assessment would be useful for other Western Australian communities that may be impacted by greenhouse gas reduction policies.

1.6 Methodology

A literature review addresses the first research sub-aim. A case study addresses the second and third sub-aims, drawing on resilience literature, government and industry data, newspaper articles, local histories and interviews with key informants. The fourth sub-aim is addressed by considering the outcome of the case study in the broader Western Australian context.

Case studies are a useful method of providing an in-depth exploration of a real-life system, and in this thesis serve both an intrinsic purpose (that is, the interest lies in the particular circumstances of the system being studied) and an instrumental one, meaning that the case study is intended to provide insight into a general issue (Stake, 2000; Flyvbjerg, 2006). It is hoped that analysing Collie's resilience will expose patterns and trends relevant to other communities that are also facing transition, as well as providing useful lessons about how to conduct resilience research.

The author interviewed 16 key informants who live in Collie and are active in local government, industry, business or the community. They ranged in age from people in their twenties to those in their seventies and included eight men and eight women and one Indigenous informant. Six open-ended questions relating to interviewees' views about the future of Collie, its strengths and weaknesses and vulnerability to policies to cut greenhouse gas emissions were asked (Appendix 1). Some interviews took more than an hour and all were conducted in the informant's home or private office, and on two occasions, by telephone. All interviews were recorded and transcribed. In

consultation with Murdoch University Research Ethics Committee, it was decided that interviewee confidentiality was essential to protect identity in the context of a small town. However, where it is possible to do so, general references to key informants' areas of expertise are included.

1.7 Thesis structure

Chapter 2 discusses the emergence of resilience thinking as an approach to sustainability assessment, giving consideration to issues that arise in assessing resilience in social systems, as opposed to purely ecological systems.

Chapter 3 introduces the case study, including why Collie was chosen, a brief description and discussion about what features are being assessed for resilience and why.

Chapter 4 provides a temporal scale perspective on Collie's resilience story to date, linking past events to its current condition using the metaphor of an adaptive cycle.

Chapter 5 discusses various threats to Collie's coal industry and the possibility of a regime shift.

Chapter 6 considers Collie's capacity to adapt to a decline in the coal industry.

Chapter 7 considers the role of perverse resilience in relation to Collie.

Chapter 8 synthesizes findings from the case study and considers whether resilience assessment is useful for other Western Australian communities facing transition.

Chapter 9 reviews the key findings from the literature review and case study and identifies areas for further research.

Chapter 2: Defining Resilience

Resilience thinking evolved from the field of ecology in the 1960s but has increasingly been applied to social sciences, in particular as a framework for analysing adaptive change towards sustainability (Holling, 2001; Berkes et al., 2003; Folke, 2006). This chapter describes key concepts in resilience thinking, including challenges that arise for researchers as a result of differences between ecological and social systems.

2.1 Ecosystem resilience versus engineering resilience

Resilience is "a system's capacity to absorb disturbances without a regime shift" (Walker & Salt, 2006: 38; Gunderson & Holling, 2002: 50). This definition, sometimes termed 'ecosystem resilience' (Holling, 1973), recognises the potential for a system to permanently shift from one set of structures and functions to another, effectively losing its identity: a process referred to as 'regime shift'.

In contrast, the traditional 'engineering resilience' view is that there is only one natural or normal range of conditions for a resource or ecosystem and therefore managing it is simply a matter of knowing how fast it will bounce back after being depleted or damaged, with the assumption that it will always be able to do so.

Resilience writers believe that because conditions influencing complex systems are generally transient, managers of complex systems will always be challenged by surprise and incomplete information (Holling, 1973). In contrast, engineering resilience assumes linear, predictable, cause-and-effect relationships in the flow of resources, and therefore supports exploiting a resource to its limits, with the expectation that the system will recover in the same way as it has in the past. Engineering resilience overlooks the multiple, cross-scale influences affecting a system at any time and thus ignores the need

to enhance the system's capacity to adapt to changing, unplanned circumstances. In contrast, resilience writers recognise that redundancy and diversity are needed in the system to buffer against worse-than-expected impacts and to provide opportunities for the system to reorganise when necessary (Berkes et al., 2003; Folke, 2006; Walker & Salt, 2006).

Allison & Hobbs (2004) describe a regime shift associated with dryland salinity resulting from land-clearing in Western Australia's wheatbelt. The region's hydrology is not expected to recover until between 2050 and 2300 and the flow-on effects include biodiversity loss, reduced agricultural production, eroding of Indigenous cultural connections and disintegration of farming communities. Combined, these cause a loss of regional identity, form and function. Evans (2008; 2009) describes how coalmining in the Hunter Valley has damaged local rivers, air quality and social capital and is pushing that region towards a regime shift. Both studies demonstrate Berkes et al.'s (2003) finding that gradual degradation of environmental and social capital is often ignored until too late. System managers are often caught by surprise by the effects of slow and even predictable trends. Recognising this, Walker & Salt (2006: 146) identify "awareness of slow variables" and "tight feedback signals" as important attributes of resilient systems.

Resilience thinking draws on complexity theory by recognising that each system is nested in time and space within other systems, termed a 'panarchy' (Gunderson et al., 1995; Gunderson & Holling, 2002). Therefore in assessing a system such as Collie, it is important to understand its history and cross-scale influences upon it today. Collie's condition today is the result of its geological history, Indigenous occupation over millennia and the period since European colonization and industrialization. Collie is also influenced by social and biophysical systems of which it is part, such as the south-

west region, the State of Western Australia, the nation and the global ecosphere. Smaller systems within Collie, such as community groups, waterways, businesses and households also influence Collie's condition. As Holling et al. (1998: 354) note: "Social and ecological systems are nested in time and space from the cell to the ecosphere, with numerous non-linear feedbacks".

2.2 Adaptive cycle

Since Holling's 1973 paper on ecological resilience, he and other resilience writers have gone on to identify a four-stage adaptive cycle that ecological and social systems appear to undergo (Holling, 1986; Gunderson & Holling, 2002) – see Figure 1.

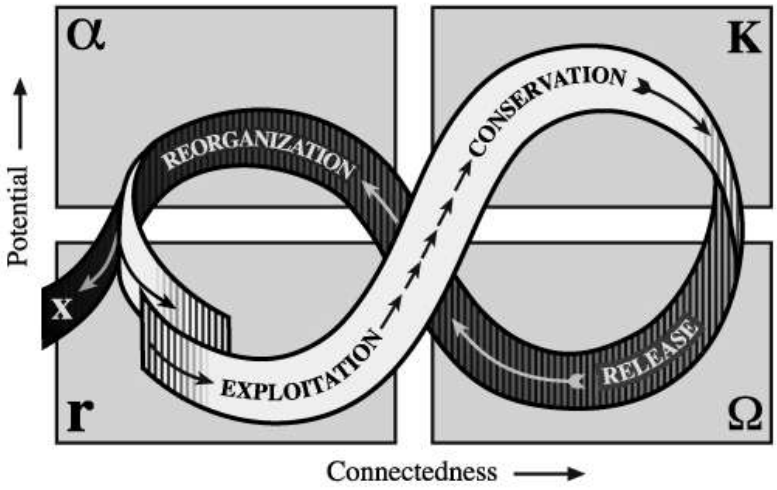

Figure 1. Adaptive cycle (Gunderson et al., 2002)

Walker & Salt (2006) describe these phases as:

- **Exploitation**, referring to rapid growth that often occurs soon after a resource or business idea is discovered. Actors such as colonizing species or business entrepreneurs rapidly spread across the system or expand their business.

Components of the system are weakly connected with the rest of the system and the enterprise may be subject to collapse.

- **Conservation**, where competition has forced the species or human actors exploiting a resource or market to develop resistance to threats by becoming more efficient. Features of this system include: specialization and dominance by certain components (for example, businesses target niche markets or expand for economies of scale); the accumulation of capital (for example, biomass in the form of nutrients stored in forest floor humus); and greater interconnectedness and regulation (for example, new entrants, such as rival species or businesses, are excluded). Late in the conservation phase, the system becomes even more tightly interconnected and deviation from the status quo is increasingly difficult: the system becomes more rigid, less able to adapt to changed circumstances and ultimately less resilient.

- **Release** describes the system's collapse, caused by its rigidity making it unable to absorb or adapt to external shocks or internal trends, such as the using up of a resource. It is possible that in this phase a regime shift will occur, with loss of form, function and identity.

- **Reorganisation** may follow the chaos or vacuum created by release, as hitherto excluded elements are given opportunity to grow. New businesses, political systems or species may move in to seize markets, power or resources. With the future up for grabs, a new phase of exploitation may begin and the cycle continues.

2.3 Adaptive capacity

Resilience writers tend to emphasize the need to monitor whether systems are vulnerable to shifting from one regime to another, with the implication that the current regime is desirable and the new regime is undesirable (Gallopin, 2007). This assumption may have arisen because many systems studied to date are ecological systems in the exploitation or conservation phase, such as wetlands, coral reefs or farming regions (see Walker & Salt, 2006; Resilience Alliance, 2010). From a resource management view, avoiding regime shifts for the sake of protecting existing biodiversity or ecosystem services is desirable.

However, it is not always possible to maintain the status quo and a single-minded focus on stabilization also ignores the resilience-enhancing opportunities created by release and renewal (Berkes et al., 2003; Folke et al., 2003). The economist Joseph Schumpeter used the phrase "perennial gale of creative destruction" (Schumpeter, 1984: 4; orig. pub. 1942), arguing that release and renewal was healthy for business and industry, while Holling (see Walker & Salt, 2006: 79–81) has described how fir forests naturally undergo collapse and renewal in order to maintain long-term health.

System release may occur in a destructive way that causes suffering or it may be managed so that a smooth transition and swift reorganisation phase occurs, with essential features of the system maintained. Resilient systems are those that have strong adaptive capacity; in other words, they are able to either absorb change, or following a release phase, reorganise (Folke et al., 2003). In assessing the resilience of a social-ecological system, resilience researchers therefore not only ask 'How close is the system to a regime shift?' but 'What is the system's capacity to adapt?'

Folke et al. (2002) summarise adaptive capacity in social-ecological systems as: learning to live with change and uncertainty; nurturing diversity for reorganisation and renewal; combining different types of knowledge for learning; and creating opportunity for self-organisation. To this, Walker & Salt (2006) add diversity, variability, modularity, acknowledging slow variables; tight feedback signals; social capital; innovation; and 'overlap' or redundancy in governance and ecosystem services as attributes of adaptive capacity, while Levin (1999) has a slightly different list of eight 'commandments' of environment management. However, as Folke et al. (2002) note, how society reorganises following change is one of the most neglected and the least understood aspects of conventional resource management and science.

2.4 Concerns about resilience research

Leach (2008), Gallopin (2007) and Ráez-Luna (2008) have identified the need for further clarification of resilience concepts. Much resilience research on ecological systems to date is positivist since it is generally agreed that protecting biodiversity and other ecosystem services is desirable. Yet Ráez-Luna (2008) and Evans (2009) suggest that in social-ecological systems, whether some structures or functions are desirable depends on one's personal view. Failing to address the issue "resilience of what, to what … for whom?" (Lebel et al., 2006) can lead to confusion about whether resilience is good or bad and whether writers such as Berke et al. (2003) are correct in suggesting that resilience is synonymous with sustainability. Leach (2008) concludes that resilience researchers need to address these normative questions, and attach the term resilience to a person, form or organisation, rather than discuss it in the abstract.

Ráez-Luna (2008) also expresses concern that a key difference between purely ecological systems and social-ecological systems – that is, the way that hegemony often

determines outcomes in social systems – is overlooked by resilience writers who assume social systems may be mapped in the same way as ecosystems. He notes that in social systems, "for every material flow, there are a number of ideational flows" and power is a "key organizing force" (Ráez-Luna, 2008: 325; 330). Urging resilience researchers to pay close attention to the role power plays in social-ecological systems, Ráez-Luna observes that resilience in largely social systems often takes a perverse form.

2.5 Perverse resilience and the role of power

'Perverse' comes from the Latin *perversus*, meaning 'turned the wrong way' (Collins Concise Dictionary, 1990). At a superficial level, therefore, 'perversely resilient' may simply describe ill-health, weeds or other problems that are hard to fix.[2]

However, applied to social systems, the notion of perverse resilience is more complex. Following Ráez-Luna (2008), Evans (2009) has explored how in social systems, perverse resilience may be linked by the conscious use of power by certain groups to produce outcomes that benefit them while harming others and/or the environment:

> Perverse resilience occurs where pathological social relationships that are oppressive and exploitative of humans and ecosystems are rendered resistant to change by political support, including economic subsidies (Evans, 2009: 8)

Evans (2009) applies Ráez-Luna's analysis of first and third-world power relations (whereby the first world imposes non-sustainable conditions on the third world) to the Hunter Valley, where global corporations benefit from exporting the region's coal, but in doing so damage local landscape, Indigenous heritage and environmental health.

[2] For an example of this use, see Maryland Sea Grant, 2008.

Evans finds that because so much power is vested in the corporations, they are impervious to community concerns and thus are perversely resilient.

Albrecht (2010) describes the perverse resilience of Western Australia's coal and gas industries, demonstrated by the fact that climate change concerns, peak oil and major offshore oil spills have not slowed these industries' expansion. Albrecht argues that concentrated power undermines democracy which otherwise should enhance positive resilience. Examples of this occurring include the fact that in 2010, senior staff in the Western Australian Department of Premier and Cabinet were recruited from the oil and gas industry in order to conduct negotiations on behalf of the Government with that industry (Emerson, 2010) and by the board membership of one of the most politically influential media outlets in Western Australia, *The West Australian* newspaper, which is sprinkled with chief executives of large resources industry firms, including Westrac Holdings Pty Ltd, Rio Tinto Iron Ore and Woodside (WA Newspapers Group, 2010).

Although perverse resilience as described by Ráez-Luna (2008), Evans (2009) and Albrecht (2010) is arguably a common problem, the term is yet to appear widely in resilience texts. For example, Walker & Salt (2006) refer to perverse subsidies, increasing sunk costs, and increased command and control simply as dangers typical of the rigidity that affects late conservation phase systems. However, this runs the risk of overlooking a key difference between purely ecological systems and social systems: the conscious use of power to control outcomes occurs throughout human systems but it does not exist at all in ecosystems. There are no perverse subsidies in Nature.

Chapter 3: Introducing the case study

In conducting a resilience assessment, it is helpful to identify the system's boundaries and this is best done by relating the system to the key issue of interest (Resilience Alliance, 2007). Collie shire,[3] including the geographic area under shire jurisdiction and the residents and business, community and government organisations active within it is the subject of this case study, for the reason that Collie is Western Australia's only coalmining region and hosts most of the State's coal-fired electricity generation.

3.1 Description

Biophysical environment

Collie shire (Figure 2) is 200km south of Perth and covers 1,685sqkm. Situated 60km inland from the coast at Bunbury, it is 170–200m above sea level in a break in the Darling Escarpment known as the Collie River Valley (Wheadon, 2009). The Darling Plateau stretches to Collie's north and south, while to the west is the low-lying Swan Coastal Plain and to the east, undulating farmland giving way to the State's Wheatbelt region.

About 75 per cent of the shire is State forest, including the 170sqkm Wellington National Park, with the remaining land occupied by industry, farming and human settlement (Wheadon, 2009). The Harris and Bingham rivers enter the shire from the north and east, joining Collie River east branch north of Collie, which joins the Collie south of Collie and flows through the Park to the coast.

[3] 'Collie shire' and 'Collie' is used here to describe the geographic location covered by shire boundaries, while 'the Shire of Collie' and 'Collie Shire' refers to the government authority.

Jarrah forest dominates the valley and is in fair condition, despite changed hydrology and salinity, feral animals and increasing fragmentation (Australian Natural Resources Atlas (ANRA), 2009a). Significant fauna include red-tailed black cockatoos, Baudin's black cockatoo, Carnaby's black cockatoo, chuditch and the western brush wallaby (GHD, 2009). Land-clearing, clearing of river banks and salinity have had significant impacts on biodiversity in Collie's rivers, home to native fish, tortoise and marron (Department of Water (DoW), 2009).

The Collie River has also been affected by an 8km section through central Collie being dredged in the 1960s to prevent flooding and by many water supply dams (ANRA, 2009b). While some tributaries are fresh, others are brackish or saline and salinity is increasing (ANRA, 2009b).

The Collie Coal Basin is a north-westerly trending valley covering 224sqkm to the east of Collie, divided into the Cardiff and Premier sub-basins (Figure 4) (GHD, 2009). This basin is underlain by the granite basement of the Yilgarn Craton and lies within the Collie groundwater area (Figure 5).

Collie has a temperate Mediterranean climate with warm dry summers and cool wet winters (GHD, 2009). Its mean annual rainfall based on all historical data is 935mm (Bureau of Meteorology (BoM), 2010a). However, for the period 1985–2007, Collie's annual rainfall averaged 827mm, in keeping with the 10–15 per cent decline in annual rainfall across south-west Western Australia since the 1970s, attributed to global climate change (CSIRO, 2009a; IOCI, 2009).

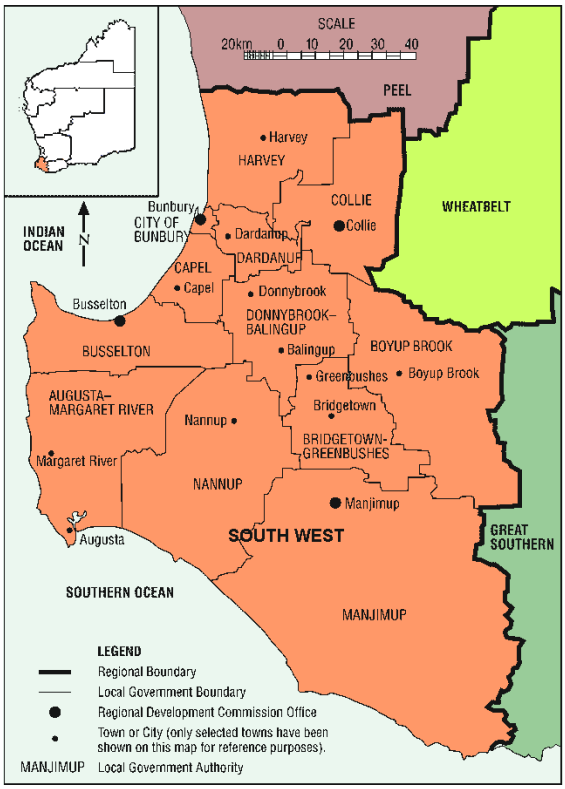

Figure 2. Collie Shire (Department of Regional Development and Lands, 2010)

Figure 3. Satellite image (Google Earth, 2010)

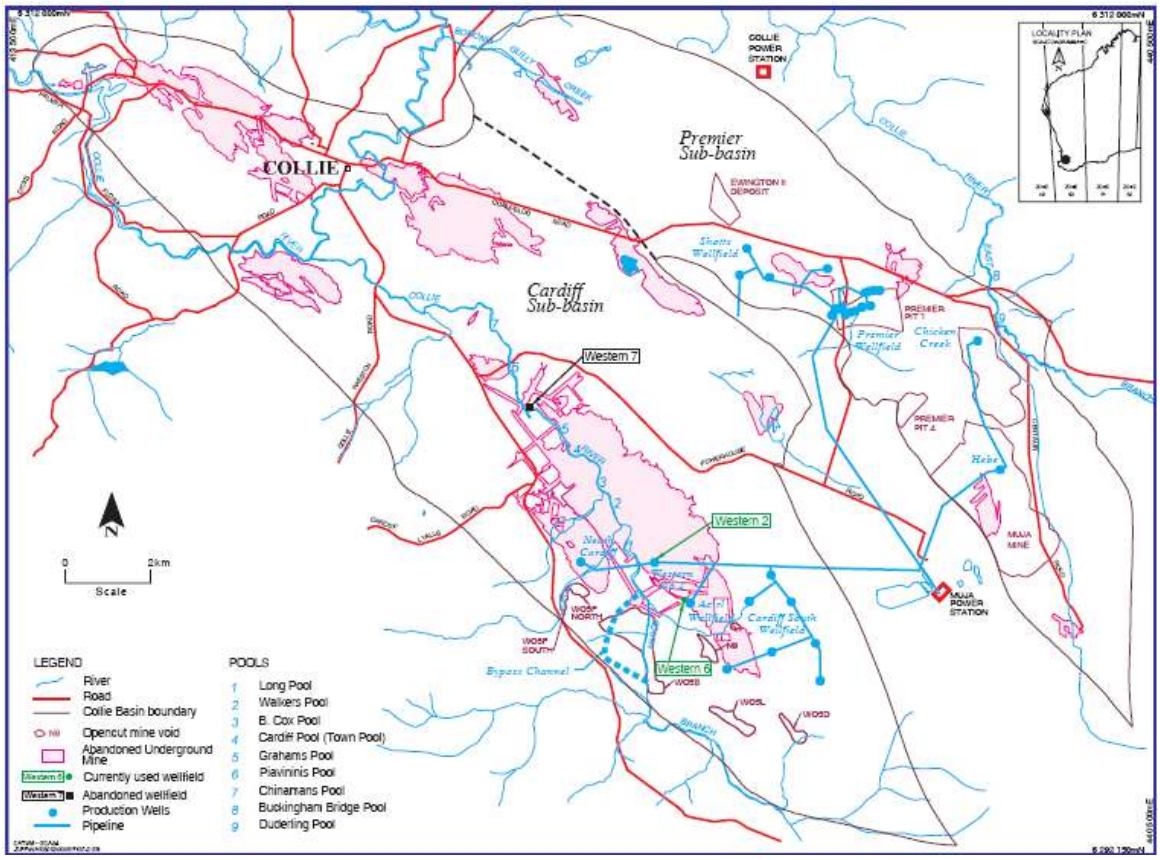

Figure 4. Collie Coal Basin (Varma et al., 2007)

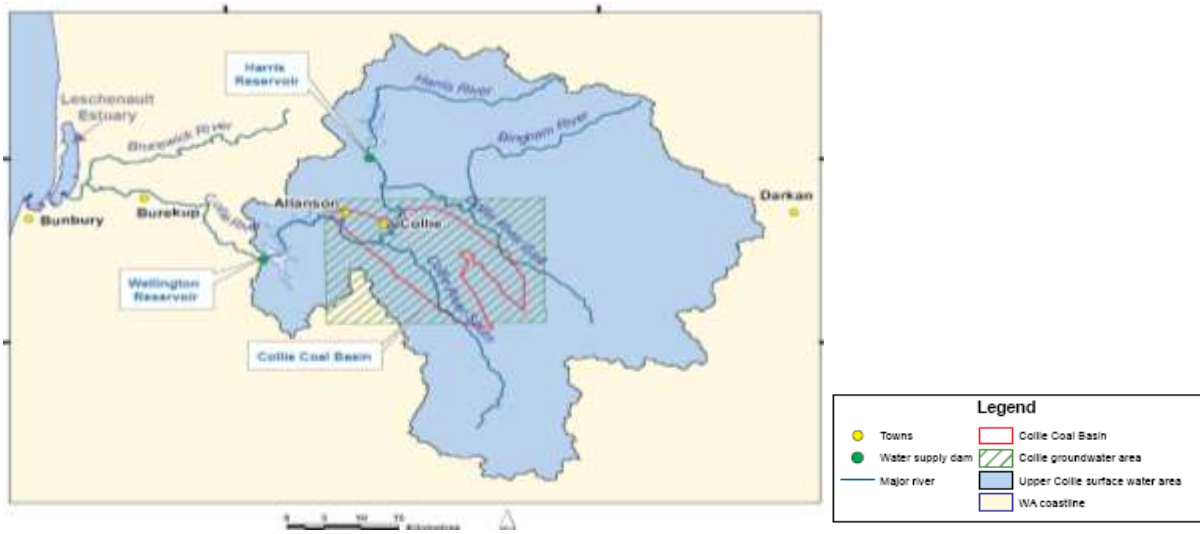

Figure 5. Collie groundwater area (Department of Water, 2009)

Society

Collie is home to about 9,000 people, most of whom live in Collie town, while others live in the settlements of Allanson, Cardiff, Collie-Burn, Mungalup, Preston Road, Buckingham, Shotts, Worsley, rural lifestyle estates and farm holdings (Wheadon, 2009; South West Development Commission (SWDC), 2010). The shire's exact population is disputed. The Australian Bureau of Statistics estimated it to be 9,151 in 2008 (up from 8,613 people in 2006) (ABS, 2010), but local stakeholders claim the figure is closer to 10,000 (Tilbrook, 2010a). The Western Australian Planning Commission projects an annual 0.39 per cent decline in the shire's population to 2031 but the Collie Shire believes the population will grow at 2 per cent annually (Figure 6) (Wheadon, 2009; SoC, 2008).

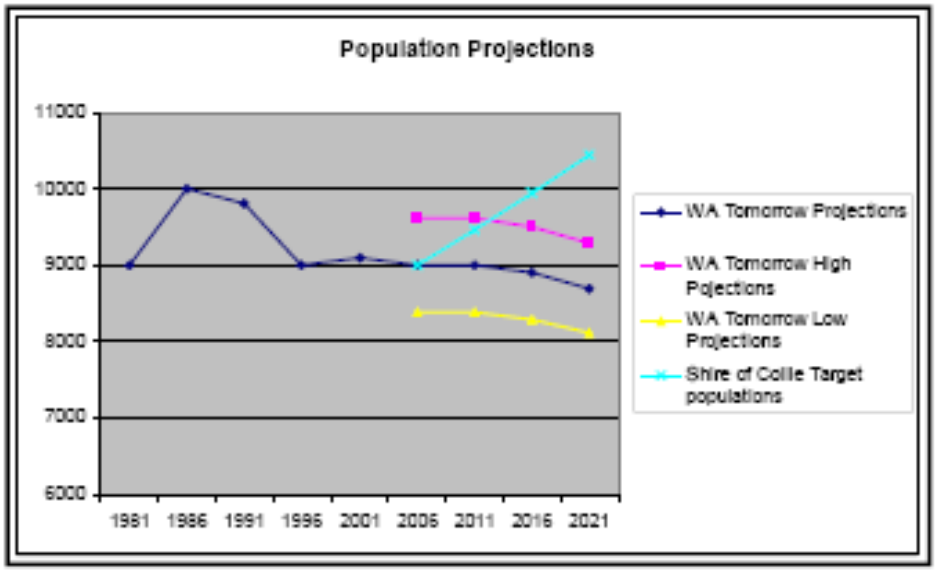

Figure 6. Population projections (Shire of Collie Strategic Plan, 2008)

In the 2006 census, 51 per cent of Collie's residents were male and 49 per cent female (ABS, 2007a). Three per cent were Indigenous, children aged 0–14 made up 24 per cent of the population and 24 per cent were 55 or older. The median age was 37 years.

The Shire consists of 11 elected councillors and a large staff (SoC, 2010). Collie is represented in the Western Australian Parliament by a State Lower House State MP and State Upper House and Federal MPs for the south-west. A Shire councillor sits on the board of the South West Development Commission, a Western Australian Government authority which aims to support projects that benefit the region's economy and quality of life (SWDC, 2010).

Collie has many business, industry and community groups with interests ranging from tourism to industrial development, small business, disability services, environmental protection, heritage, sports and Indigenous development. The shire has medical and dental services, a hospital, a high school and five primary schools, aged care services, a public library, sporting facilities, hotels, cafes, restaurants, supermarkets and shops.

Economy

Figure 3 shows coalmining by Wesfarmers Premier Coal and Griffin Coal to the east of Collie (grey area) and Worsley Alumina's bauxite mining and associated alumina refinery to the west (red). Wellington Dam is visible west of Collie.

Some Collie coal is sent by train to Kwinana for power generation and cement manufacturing, some to Worsley alumina refinery and recently, some has been exported overseas. However, most of the coal fuels coal-fired power stations east of Collie, including Bluewaters 1 and 2 (total 412 megawatts in capacity) owned by Griffin Energy, and Collie and Muja C–D power stations (340MW and 854MW), run by Verve

Energy and owned by the Western Australian Government. Planned expansions include Griffin's proposed Bluewaters 3 and 4 power stations (a total 416MW), refurbishment of Verve's 240MW Muja A-B power stations and Perdaman Chemical and Fertilisers' plan to build a $3.5 billion coal gasification plant which will supply urea (a fertilizer) to India (Griffin Energy, 2010; Verve Energy, 2009; GHD, 2009a).

Mining and mineral processing across the entire South-West region was worth just under $2 billion in 2008–2009, with alumina making up 66 per cent and coal 17 per cent, or $330 million (SWDC, 2010b). Collie's other industries include timber, farming (mainly sheep and meat cattle), tourism, aquaculture and viticulture, with agriculture estimated to be worth $6.5 million annually (SWDC, 2010; ABS, 2010).

In the 2006 census, Collie's unemployment rate was five per cent and the median weekly household income was $965, $62 less than the national median (ABS, 2007a; 2007b). Men were more likely to be in paid work than women and the five most common industries of employment for persons aged 15 years and over were:

- coalmining (fifteen per cent);
- school education (seven per cent);
- basic non-ferrous metal manufacturing (five per cent);
- electricity generation (four per cent);
- cafes, restaurants and takeaway food services (four per cent) (ABS, 2007a).[4]

[4] Other types of employment were so diverse as not to be specified.

3.2 Resilience 'for whom' and ‘of what’

This study aims to assess Collie's resilience for the benefit of current and future residents of the shire, using a sustainability perspective that places equitable emphasis on the economy, ecology and society.

Interviews with key informants, the Shire's *Strategic Plan*, newspaper reports, local histories and government agency reports helped identify the structures and functions of the shire that are important to residents. Table 1 provides a summary of the features and functions of Collie that appear essential to the wellbeing of current and future residents. It may not be conclusive but it represents the ‘stand-out’ issues.

Table 1. Collie’s essential features

Essential feature	Description
Employment opportunities	Many key informants expressed a view that employment opportunities were essential for Collie’s future. Past job cuts were detrimental to community happiness and local businesses. In 2010, job-shedding and uncertainty at Griffin Coal reduced spending at local businesses. Informants noted that many of Collie's industry jobs today are held by people living outside the shire.
Stable population	As demonstrated by the Shire’s objection to suggestions that Collie’s population is declining, a stable or growing population is highly valued by Collie people. Past patterns show population is strongly linked to the availability of jobs, for example, the loss of 350 coalmining jobs in the mid-1990s caused many families to leave Collie. However, a recent trend towards retirees moving to Collie is driven by

	affordable real estate, and according to informants, has led to little economic benefit.
Local services	Many key informants cited the importance of a range of public and business services, while some also strongly valued good road, rail and port infrastructure for industry.
Water supplies	Local groundwater and surface water supplies are essential to sustain Collie's ecology, industry, human water supply and amenity (DoW, 2009). While options to boost local supplies include water recycling and desalination (of seawater or saline river water), Collie's groundwater supplies and rivers have long been seen as key assets requiring protection (DoW, 2009; Williams, 1979). Many key informants spoke about the need to balance competing demands on water, with many also expressing concerns about local river health.
Rural lifestyle	Key informants praised Collie's peacefulness and safety, contrasting this with city life. Some complained that mining noise kept them disturbed them at night but others did not hear or object. Parents considered Collie a safe place to bring up children but some informants expressed deep concern about Collie teenagers getting into crime out of boredom.
Clean air	Potential impacts on human health from emissions from current and proposed industry were a strong concern for several key informants. Collie volunteer organisation, Rural Action Group, is so concerned that it is conducting its own risk assessment of emissions from Perdaman's proposed urea plant.
Sense of place	Indigenous and non-Indigenous key informants strongly identified as

	being from Collie, including both those born in Collie and those who arrived later in life. Some informants were the third or fourth generation of their family to live on their property in Collie and spoke passionately about their connection to the land.
Community friendliness	The Shire's *Strategic Plan* cites inclusivity in its vision (SoC, 2008). Key informants described Collie's friendliness. When tragedy or illness strikes local families, other residents fundraise for them. However, many informants expressed concerns about declining participation in volunteer groups and many blamed this on 12-hour shifts and more workers living outside Collie, reducing camaraderie between miners.
European heritage	While many of Collie's early buildings have been destroyed, many remain and are described in a heritage flyer produced by Collie Mainstreet Inc. Signs around town provide information about the town's heritage and there is an active Collie Heritage Group. Heritage appeared valued for both tourism potential and because of community pride in it.
Indigenous values	The Shire's *Strategic Plan* cites ''research opportunities to recognise and embrace local indigenous community'' as one of its objectives (SoC, 2008: 14). Three key informants, including an Indigenous person, wanted to increase job and leadership opportunities for Indigenous people. Recent newspaper articles and anthropological surveys show Collie's Indigenous people care deeply about Indigenous heritage.
Natural attractions	The Collie Shire and Visitors' Centre strongly promote Collie's rivers, forests, water supply dams, lakes formed in mining voids and hiking and cycle trails. Many key informants praised Collie's natural

	attractions and range of outdoor activities.
Biodiversity	The shire is home to significant fauna and ecological communities protected under State and Federal legislation. Some key informants wanted greater protection of native terrestrial and aquatic biodiversity from threats such as clearing, weeds, salinity and falling water tables.
Good governance	Many key informants said good governance by Collie Shire was essential, with roughly half praising the Shire and half critical. Good representation at a State and Federal level was also valued. Some informants expressed a need to increase diversity on the shire council.

Chapter 4: A resilience history of Collie

A study of past changes to a complex social-ecological system may reveal patterns and increase understanding about the likely effect of trends and interventions today (Resilience Alliance, 2007). In addition, examining an industry in terms of an adaptive cycle helps us to understand its outlook for the future (Walker & Salt, 2006). However, as Walker & Salt (2006) also note, the phases of exploitation, conservation, release and reorganisation do not always follow each other sequentially; for example, release may lead straight to exploitation or conservation rather than reorganisation.

The author acknowledges heavy reliance in this chapter on H.W. Williams' *One Day in Collie* (1979), Wesfarmers Premier Coal's *50 Years of Powering Western Australia* (2003) researched by Dr Sue Graham-Taylor, and John Bird's *A Rich and Diverse Heritage* (2010).

4.1 The landscape

The Collie coal measures are around 300 million years old (New Collie Coal, 2010). They were formed within a depression in the Archaean Yilgarn Craton by compaction of swampy vegetation during the Permo-Carboniferous era (Geological Survey Western Australia (GSWA), 1990; Williams, 1979). This depression, known as the Collie Coal Basin, was formed at an earlier age by tectonic movement (Le Blanc Smith, 1993).

The basin comprises a 1km-thick sequence of Permian sedimentary rocks including sandstone, shale and coal, beneath a veneer of chalky Cretaceous rocks (GSWA, 1990). Up to 55 significant coal seams 1.5–5m thick have been identified in the basin with the 13m Hebe seam by far the thickest (Figure 7).

Figure 7. Hebe seam (black at base of picture, beneath thinner coal seams and grey overburden). Author's photo.

Between the Permian age and the present, sea levels rose and fell, with the Collie Basin at times forming an inland sea (Williams, 1979). As sea levels fell during the last ice age, water drained back into the ocean, eroding river banks to form the Collie River Valley. This system extends 130–150km inland, draining 3000sqkm of farmland, wetland and forests from the Yilgarn Plateau in the western Wheatbelt through to the coast at Bunbury (Beard, 1999; ANRA, 2009b).

4.2 Indigenous cultural connections

The earliest evidence of human occupation in south-west Western Australia is at Devil's Lair near Margaret River, dated 48,000 years old (Turney et al., 2001). Within Collie

shire, two surveys north and north-west of Collie town have identified more than 100 archaeological sites including quartz stone tools dating up to 3,000 and 6,000 years old (Pearce, 1982; O'Connor et al., 1989). Artefact densities in these surveys – at two and five sites per sq km – are comparable to other South-West locations, although less dense than on the Swan Coastal Plain (O'Connor et al., 1989).

Of 13 south-west Indigenous groups once collectively known as the Bibbulmun and now referred to Nyungars, the Kaneang regarded Collie as their territory, while the Wilman occupied Collie's northern and eastern areas (Tindale, 1974 and Berndt, 1979, in Goode & Harris, 2009).

It appears that the Bibbulmun concentrated around the coast, estuaries, swamps, lakes and rivers of the coastal plain in summer, and moved into jarrah forest on the Darling Plateau in other months, including around Collie (Williams, 1979; Anderson, 1984; O'Connor et al., 1989). A track used by settlers between Bunbury and Kojonup, which crosses the Collie River may have first been used by the Bibbulmun (Williams, 1979, Goode & Harris, 2009). Early explorers, including Dr Alexander Collie after whom Collie was named, Lieutenant Bunbury and Surveyor-General Lieutenant Roe reported seeing Aboriginal people, or evidence of them, at the Collie River mouth and upstream (Goode & Harris, 2009).

Nyungars today associate the Waugal, a Dreamtime serpent-like ancestor known across the south-west, with many of Collie's river pools including Bolton's, Wuridjong, Telfer's, the pool where Wellington Dam now exists and the Mungalup Road Spring (O'Conner et al., 1989, Bird, 2010). Minninup Pool is still used by Indigenous people for ceremonies following a death, and others say that the Waugal causes illness amongst

Nyungars who fail to care for their country or break cultural protocols (Beckwith Environmental Planning (BEP), 2009).

Figure 8. Minninup Pool. Author's photo.

Registered Aboriginal sites in the shire include Gibraltar Rock south of Collie and many sites along the Collie River, reflecting the waterway's importance for food (marron, fish and long-necked turtles), drinking water and swimming (Bird, 2010; BEP, 2009). Indigenous occupation along the rivers continued throughout European colonization, with permanent Indigenous camps formed at Walls End, Boronia Gully, Collie Aboriginal Reserve and Collie River East Camp (Williams, 1979; O'Connor et al., 1989; BEP, 2009; Bird, 2010).

Indigenous people today describe seasonally available bush tucker in the shire, with yellow wattle bloom in spring signalling that kangaroos and emus are fat and October–

November being the best time for berries (BEP, 2009). However, despite the continued presence of an Indigenous population in Collie today (forming a slightly higher proportion of the local population than the national average), there is little public information about Collie's Indigenous history and culture. Most local histories focus on the 1880s–present (see Williams (1979),[5] Stedman (1988), Coote (1991) and Bird (2010)). Williams (1979) and Bird (2010) acknowledge this absence of information.

Figure 9. Public panels, Baarnimarr Reconciliation Park, central Collie. Author's photo.

4.3 1880–1902: Exploitation

In either 1882 or 1883, a shepherd, George Marsh, noticed rocks surrounding his campfire had ignited. Whether his master, pastoralist Arthur Perrin, was with him then

[5] Archaeological surveys were conducted after Williams' book was published.

and deserves credit for identifying the rocks as coal is disputed, but by 1889, efforts to explore for coal in the area which would become known as Collie had begun (Williams, 1979; Bird, 2010).

Because of the need to power railways, the Western Australian Government was keen to develop a coal resource and had earlier advertised a £1000 reward to anyone who discovered coal in the State (Bird, 2010; WPC, 2003). After Perrin and his associates identified the Collie measure, a Government specialist talked up business interest in developing it and later, when the first firm to drill for coal ran out of money, a Government team took over (Williams, 1979).

By 1894, the seam was sufficiently delineated to show it could power the State's railways but there was competition from Newcastle coal, which had a higher calorific value (Williams, 1979; Coote, 1991). Western Australian engineer-in-chief C. Y. O'Connor convinced the Government that it should support Collie coal, by doing further drilling (followed by the release of another highly optimistic Government report), opening up leases for coalmining and building a railway to Collie (Williams, 1979; Bird, 2010). Thus a precedent for Government assistance to protect Collie coal from competition was established at the industry's outset.

1898–1902 saw great economic, social and civic growth for Collie, with seven hotels, a post office and public hall built, streets gazetted and many church and sports groups and new businesses established (Williams, 1979). However, despite developing "culturally, politically, commercially and civically, at a revolutionary rate", these activities "were built on the promise of economic potential, and not on the reality of the economic strength of the coalmining industry, which was somewhat in the doldrums" (Williams, 1979: 52). The West Collie Company, contracted to supply coal to the

Government, shut in 1898 after encountering more shale and less coal than expected; no other private firm was willing to invest, so following pressure by Collie's civic leaders, the Government released tenders to operate a Government-owned mine (Williams, 1979; Bird, 2010).

Williams (1979: 50; 52) describes Collie society in these early days as "virile" and "flex(ing) its muscles". Civic development had been stimulated by commercial growth and by 1902, Collie considered itself an "important and progressive urban centre" (Williams, 1979: 52). This proud turn-of-century, identity-forming period shows that social and economical growth can occur simply on the basis of optimism.

Figure 10. Frieze above the entrance to Collie Mineworkers Institute, built 1952. Author's photo.

4.4 1902–1950: Conservation

Slowly, Collie's struggling coal industry grew and settled into a steady growth or conservation phase. The early twentieth century was marred with disputes over pay (leading to union activity), on-off lobbying of Government when the industry hit trouble and several Government interventions, including a select committee inquiry into pricing, compulsion of the railways to buy Collie coal and two Royal Commissions (Williams, 1979).

By 1918, Collie had endured "three decades of over speculation and over optimism" in coalmining (Williams, 1979: 90). Despite this, Collie's population kept growing, thanks partly to diversity in the shire's economic base, including timber milling (which employed more men than coal did in the early years), agriculture, food industries, railways and brickworks (Williams, 1979; Bird, 2010; Coote, 1991).

The 1920s and 1930s saw expansion of the coal industry and although the Great Depression slowed timber and coal demand, Collie people were well-fed thanks to abundant game, river fish and expanded local fruit, dairy, sheep, cattle and grain production (Williams, 1979; Coote, 1991). During this period, Amalgamated Collieries operated as a virtual monopoly, despite the establishment in 1927 of Griffin Coal Mining Company (Williams, 1979; Bird, 2010). As Walker & Salt (2006: 77) note, this domination of an industry by one business is typical of the conservation phase: capital tends to accumulate in one actor and there is greater interconnectedness in the industry, making it harder for new entrants to get a foothold.

In 1940, the Collie forestry district employed 310 loggers and millers: less than half the number of coalminers (Williams, 1979). However, during 1930–1960, it was still Collie's timber industry that kept Collie's economy afloat, as the coal industry underwent a

period of “stormy weather”, with yet more Royal Commissions and union disputes (Williams, 1979: 115).

By the late 1940s, electricity had emerged as a new market for coal and in 1951, Collie Power Station, built in 1930 to supply electricity to the mines, was taken over by the Government and expanded to supply Collie and nearby towns (Williams, 1979; Bird, 2010). In 1949, Western Collieries Ltd, a forerunner of Wesfarmers Premier Coal (WPC), was formed.

4.5 1950–1980: Conservation – Partial Release – Conservation

Described by Bird (2010) as “the rollercoaster years”, the post-1950 period saw two major upheavals to Collie coal. While not serious enough to be termed regime shifts (since the industry eventually recovered from both events), these small release phases in Collie coal's adaptive cycle are characteristic of late-stage conservation phase, when “increasing dependence on existing structures and processes renders the system increasingly vulnerable to disturbance” (Walker & Salt, 2006: 77).

The period began in a thriving mid-conservation phase. In 1954, Collie’s coal industry, while the most mechanized in Australia, had reached an all-time record of 1,560 employees, producing 1mtpa of coal (Williams, 1979). The shire population was as big as it is now: 8,000–10,000 people (WPC, 2003).

However, a late stage conservation phase system is never far from collapse (Walker & Sat, 2006). Competition from other fuels and the inability or refusal of Amalgamated to reduce its prices saw the Government cut its contracts in December 1960 (Williams, 1979). A total 700 coalminers lost work (Bird, 2010, WPC, 2003), creating economic and

social dislocation, and many people left Collie: "Family life was distorted by economic, psychological and emotional stresses" (Williams, 1979: 130).

In 1962, the railways switched from coal to diesel, and by 1965, Collie, once the second biggest rail service centre in the State, had virtually no rail service (Bird, 2010; Williams, 1979). Many rail-worker families also left Collie. "Empty shops and empty houses make a depressive picture: Collie had many of them," Williams wrote (1979: 131–132). Young people left and local spending and investment contracted: "The fighting characteristics of the past, when enthusiasm and optimism had overpowered economic realism, was (sic) depressed with shock," (Williams, 1979: 132).

Following shock and collapse in the coal industry, attempts were made to reorganise and revitalise Collie. Some miners were retrenched to work in deep sewerage construction and forestry and others helped build the Muja Power Station – although many of the station's construction force and later, operational staff, were newcomers to Collie, representing a change to the "closely woven social fabric of the mining and milling community" (Williams 1979: 130).

It took the 1970s oil crisis to truly revitalise Collie's economy, albeit through further vertical integration of coal. The Middle East embargo forced up oil prices, so the East Perth, South Fremantle and Bunbury power stations, all built to run on coal and later switched to run on cheap oil, were converted back to coal (Williams, 1979). Kwinana Power Station, built to burn oil, was converted to use coal and Muja Power Station expanded. Coal demand doubled, reaching 2mtpa for power generation by 1976 (Williams, 1979), and by late 1979, with the help of then Premier Charles Court's policies focused on encouraging "vigorous development of the State's coal resources",

78 per cent of south-west Western Australia's electricity came from coal (WPC, 2003: 64).

By now, timber milling had declined and many local food and agriculture businesses that had once enabled Collie to be self-sufficient for dairy, fruit and vegetables, meat and bread had closed (Bird, 2010). In 1982, following the arrival of two supermarket chains, the Collie Co-Op Store that had operated for 45 years and been the biggest of its kind in Western Australia, also closed (Bird, 2010). With these reductions in economic diversity, Collie's economic success was defined by coal as never before.

4.6 1980-Present: Conservation-Partial Release-Conservation

In 1981, it seemed that coal production was bound to expand and Collie was set for a prosperous growth phase. Embarking on an extensive drilling program, Western Collieries predicted that Collie's coalmining workforce would double to 2,000 (WPC, 2003). However, four years later, despite deals to supply coal to Cockburn Cement, Worsley Alumina (completed in 1984) and the Government for electricity generation, the company employed only 821 workers (WPC, 2003). Coal had been hit by a double blow of the 1980s economic recession and competition from Western Australia's North West Shelf gas project, completed in 1985. The Government's 20-year 'take or pay' contract to buy gas, combined with expansions in coal, resulted in a massive oversupply of energy (WPC, 2003).

Attempts to find overseas coal markets failed and in an extraordinary move, the Labor Government decided to keep Collie's industry alive by clearing 104ha of State forest in order to stockpile the coal – which would continue to be mined, albeit at half the previous rate (WPC, 2003). Then Minerals and Energy Minister David Parker explained it was essential to keep underground mining skills in the State and 800 jobs alive in

Collie (WPC, 2003). However, in an economic efficiency drive nine years later, Western Collieries shut all its underground mines, with a subsequent 350 jobs lost.

This decision, and highly politicized decision-making about coal-fired power production in the years that followed, reflect the "dangers" of late-state conservation phase described by Walker & Salt (2006: 85–87). Equally, it may reflect the perverse resilience that occurs when hegemony directs the flow of outcomes in a social system (Ráez-Luna, 2008). The decision to keep mining coal in the absence of a market is similar to paying a perverse subsidy to the industry: it encouraged the industry not to adapt to new conditions when an early adaptation strategy to match new conditions in Western Australia's energy market might have avoided greater pain in nine years' time. The decision threw a temporary lifeline to Collie's workers and signalled that the Government would look after them whenever their industry was threatened: but it failed to encourage adaptation and reorganisation.

In 1989, Wesfarmers bought Western Collieries and under a deal to sell 2.35mtpa of coal to the Government, the company's production increased (WPC, 2003). Meanwhile, debate continued at a State level about whether growing base-load electricity demand should be met by gas or coal. A Government committee recommended gas on the basis of least cost and environmental impact (WPC, 2003).

However, under pressure from a lobby group consisting of mining companies, Muja Power Station, the South West Development Authority and Collie Shire, then Labor Premier Carmen Lawrence opted for a coal-fired power station anyway, provided a 15 per cent cost reduction was achieved (WPC, 2003). The *Collie Mail* attacked the offer, claiming it was "nothing short of blackmail" (WPC, 2003: 78). Western Collieries also bit back, urging its workforce to push the Government to consider "the future of the coal

industry in terms of the future of the whole Collie community" (WPC, 2003: 78). This strategy of pressuring the minority Labor Government by equating the future of the Collie community with the future of Collie's coal industry proved effective and enduring.

As the April 1991 deadline for a decision on gas versus coal loomed, unions threatened the Government with industrial action if it opted for gas, and several thousand miners and their families were bussed to Perth to protest outside Parliament (WPC, 2003). The *Bunbury Mail* (24/4/1991) observed:

> The Lawrence Government also must be acutely aware of the effect a buoyant community spirit would have on the Labour (sic) Party's electoral prospects in Bunbury and Mitchell – arguably the most crucial seats in the State.
>
> In this issue, at least, political expediency and economic necessity are so closely interwoven that Cabinet really has no other decision to make than to give the nod to Collie. (WPC, 2003: 81).

The lobbying worked: Lawrence announced that a $2 billion, 600MW power station would be online in Collie by 1996 (WPC, 2003). However, the incoming Liberal Government in 1993 argued that only half that amount of electricity was needed (WPC, 2003) and the coal-fired Collie Power Station eventually commissioned in 1999 had a capacity of just 340MW.

At this point, it might have seemed that the coal lobby, with support from Collie's community, had partially succeeded to ensuring its workforce's long-term future. However, characteristic of systems in late-stage conservation phase, further efficiencies were required to ensure the coal industry's survival (Walker & Salt, 2006). In 1994, Western Collieries announced it would close all underground mines and convert them

to one large, open-cut strip mine (WPC, 2003). At once, 239 of its 700 miners lost their jobs, and further cuts saw Western Collieries' workforce reduced by another 100 by 1998 (WPC, 2003).

Bird (2010) writes that the cuts, combined with outsourcing at Muja, cost almost 1,000 jobs and pushed Collie into deep recession. In the words of two key informants, both former mineworkers:

> I had been with the company for 38 years, worked my way up as manager. … Just turned up to work and 'that's it' and on my way. … That was a real kick in the neck.
>
> We lost 350 when underground shut – that's why housing was cheap, people left, and everyone was a bit depressed.

The drive for increased efficiency also saw, in 1994, a move to today's 12-hour shifts: commonly two days, two nights of work followed by four days off (Bird, 2010). This is radically different from the old eight-hour shifts Monday to Friday (starting either morning or afternoon), followed by half-days on Saturdays and Sundays off. In interviews, many key informants the modern shift structure for Collie's reduced levels of social, sporting and civic participation.

Since 2000, Collie coal production has stabilised around 6mtpa (Figure 12). Today, there are only about 700 coalmining jobs in total in Collie[6] and a much smaller number (250–300) in coal-fired power generation – significantly less than the 1,560 coalminers employed in 1954 (Clayton-Utz, 2008; D'Rosario, 2010: Williams, 1978). Once the main source of south-west grid electricity, coal now supplies just 35 per cent of Western

[6] Based on 2008 mine company figures and evidence from three key informants. However, the real figure may be significantly less than 700. One mining company representative said mine workers had halved in number in the past 20 years.

Australia's grid electricity (DomGas Alliance, 2008; Office of Energy, 2006; Economics Consulting Services (ECS), 2010).

In January 2010, after nearly 83 years, Griffin Coal – the only rival to Wesfarmers Premier Coal – went into administration after defaulting on interest payments. Administrators have blamed escalating production costs and Griffin's exhausted financial resources (Kruger, 2010). Whether this business collapse will lead to a new cycle of release and reorganisation in Collie's coal industry remains to be seen.

Figure 11. Muja A-B power stations. Author's photo.

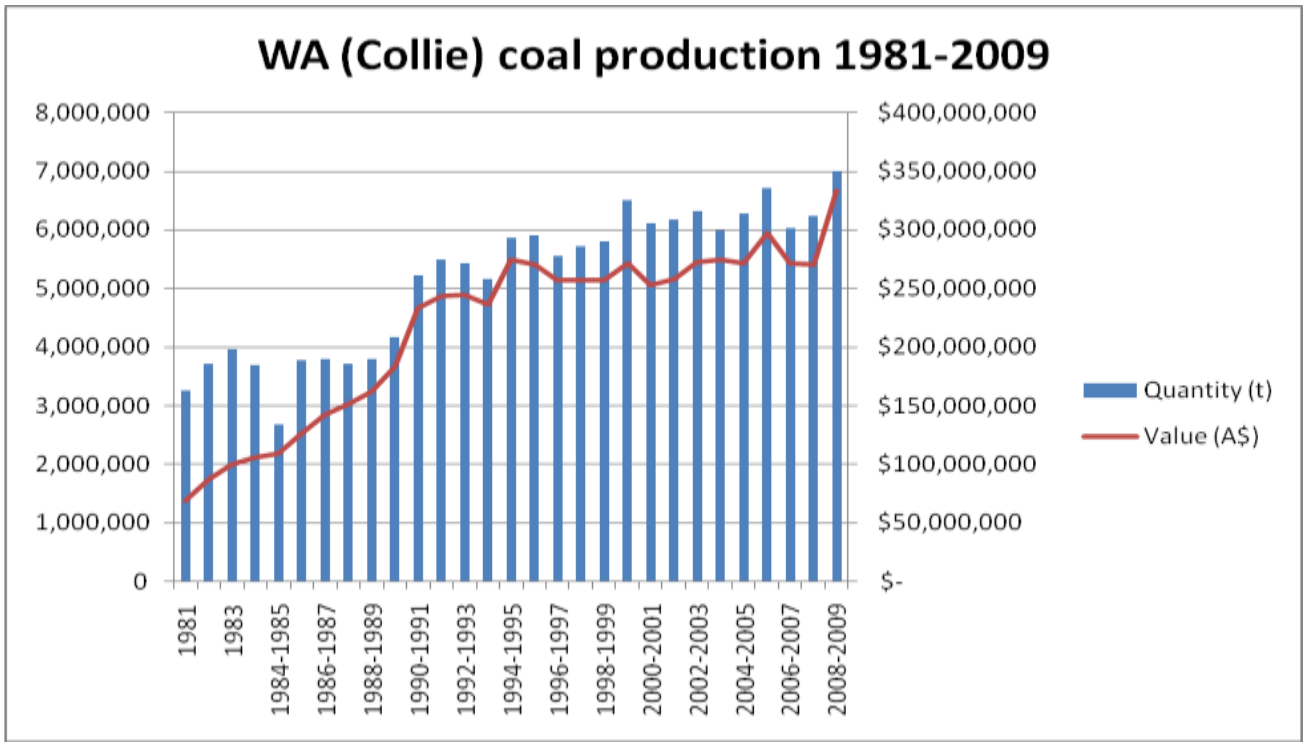

Figure 12. Collie coal production (graphic by author using Department of Mines and Petroleum Western Australia data)

Chapter 5 – Threats

Sections 5.1–5.6 explore six threats to Collie today in relation to their impacts on the 13 essential features of Collie's system described in Chapter 3.4. Some threats are slow-acting and predictable such as the gradual using up of coal reserves, while others may present as step changes and this cause surprise, for example, changes in energy markets, government policy and the climate. Section 5.7 considers whether the combined impact of these drivers is pushing Collie's coal industry towards a regime shift.

5.1 Climate change

Declining rainfall is damaging several of Collie's essential features, including water supplies, rural lifestyle, Indigenous heritage, biodiversity and natural attractions. Collie's average annual rainfall of 827mm for 1985–2007(CSIRO, 2009a: 327) is 13 per cent below the full-record mean of 935mm (BoM, 2010a), in keeping with declines across south-west Western Australia attributed to anthropogenic climate change (DoW, 2009; IOCI, 2009).

As shown in Figure 14, the CSIRO (2009a) projects that further declines in rainfall are likely to cause up to a 10m drawdown in groundwater levels over most of the Collie catchment by 2030. These falls will lead to a 20–40 per cent reduction in river head flow (CSIRO, 2009a), a situation likely to be made worse by groundwater abstraction for industry.

Many key informants expressed concern about low river levels. However, most blamed mine dewatering and the drawing of water for power station consumption rather than the changing climate. A farmer was the exception:

> This is probably the first year that (our) dam has not filled. ..Water is going to be a really serious problem. Yes, I am a believer in climate change. When you see years like this you think is it going to happen.

Local newspaper articles reveal wide-ranging impacts from reduced rainfall. Residents have complained about the loss of favourite swimming and fishing pools and the drying up of deep backyard bores (Tilbrook, 2009a; 2009b). In August 2010, a canoe race was cancelled for the first time in nine years due to low water levels (*Collie Mail*, 2010a).

Figure 13. Collie River, central Collie, July 2010. Author's photo.

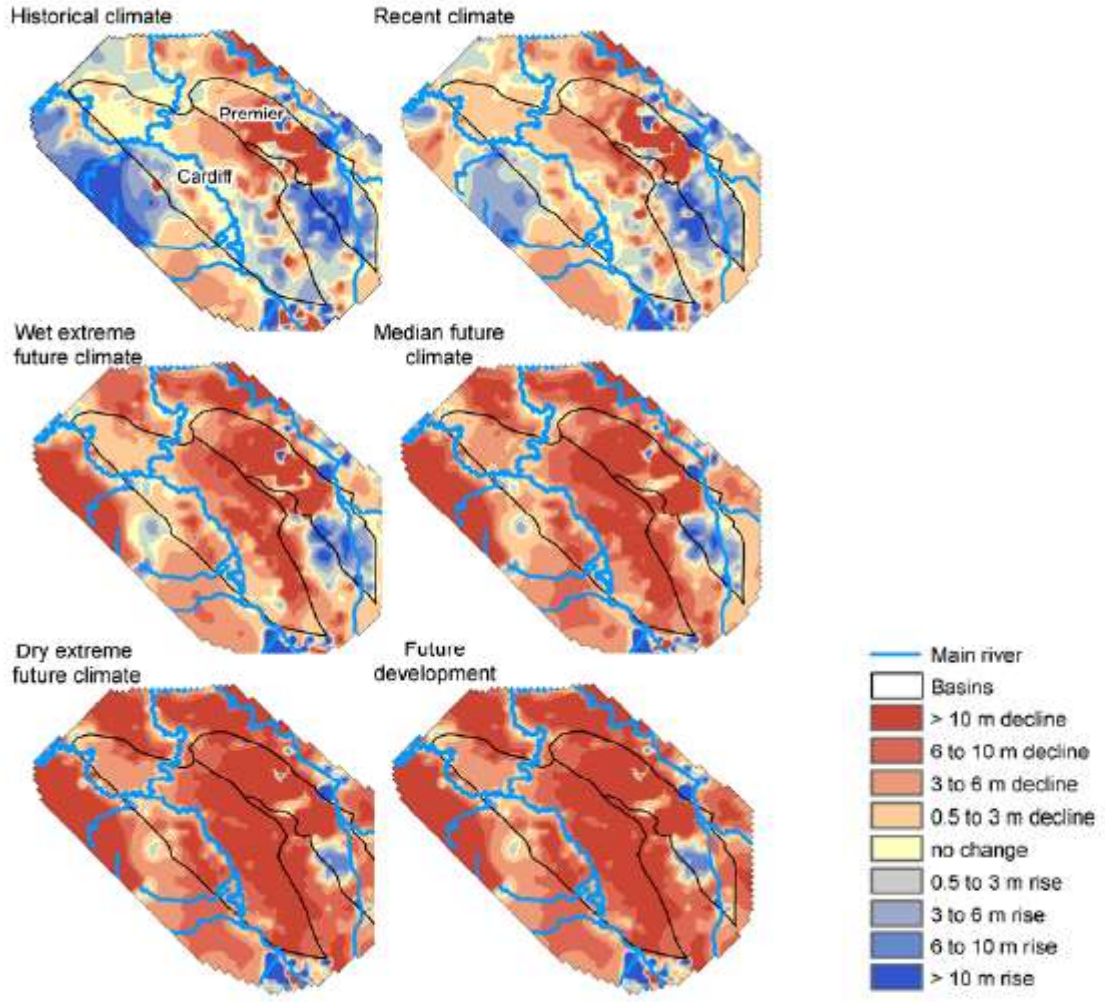

Figure 14. Collie Basin groundwater levels 2008–2030 under climate and development scenarios (CSIRO, 2009a)

5.2 Greenhouse gas mitigation policy

If Australia introduces policies that cause a scale-down of the coal industry, there will be negative impacts on jobs in Collie and therefore potential flow-on impacts for Collie's population and businesses and services (three attributes identified by this thesis

as essential for Collie's resilience). In addition, it might affect Collie's sense of place, as some informants suggested that Collie's identity is connected to its mining heritage.

On the other hand, such a scale-down would likely improve Collie's other essential features including water supplies, clean air, rural lifestyle, natural attractions, sites of Indigenous significance, biodiversity and arguably, sense of place for those who base this on Collie's natural attractions. When key informants were asked to name the main benefits of the coal industry in Collie, including to the economy, society and environment, most could only name economic benefits. As a mining industry employee stated:

> I get to drive a nice car!

Sections 5.2.1–5.2.3 explore the implications of greenhouse gas mitigation policies for Collie in more detail.

5.2.1 The political scenario

After a tumultuous 2009–2010 in Federal politics and failure to achieve clear international commitments at Copenhagen in December 2009, it is hard to guess the trajectory of greenhouse gas policy in Australia during 2010–2011, let alone by 2015–2020. Former Prime Minister Rudd failed in two attempts to usher the Carbon Pollution Reduction Scheme (CPRS) Bill through Parliament but in November 2010, the minority Gillard Government announced it would decide a carbon price in 2011 (Grattan, 2010). Meanwhile, a call by BHP Billiton's chief executive Marius Kloppers in September 2010 for the introduction in Australia of a carbon tax is also significant, given the extraordinary power of Australia's coal lobby, including BHP, on national climate policies (Pearse, 2009). As Kloppers notes, long-term institutional transformation

required to address climate change is inevitable; the only uncertainty is when it will occur:

> We also believe that such a global initiative will eventually come, and when it does Australia will need to have acted ahead of it. (Kloppers, 2010: 4)

Strangely, given BHP Billiton is Australia's biggest thermal coal exporter (BHP Billiton, 2010), Kloppers (2010: 7) also said:

> With about 90 per cent of the carbon emissions from our electricity sector coming from coal-fired power stations, Australia will need to look beyond just coal towards the full spectrum of available energy solutions.

This comment followed, in August 2010, unprecedentedly scathing comments about coal-fired electricity and carbon capture and storage by former Labor NSW Premier Bob Carr and former Liberal Party leader Malcolm Turnbull at the launch of Beyond Zero Emissions' plan for 100 per cent renewable energy in Australia by 2020 (Beyond Zero Emissions, 2010). It also follows a pre-election promise in July 2010 by Prime Minister Gillard to rule out new highly inefficient coal-fired power stations – although her announcement was attacked as green-wash since it would not stop 12 new coal-fired power stations, including those proposed in Collie, from being built (Morton, 2010).

The point of the above is that while actual policy to reduce greenhouse gas emissions in Australia in late 2010 remains largely unchanged, mainstream political rhetoric around coal has shifted. Contrast the above to Rudd's "clean coal must be part of the solution" comment in early 2007 (AAP, 2007). How much the rhetoric will lead to policy that will limit Collie coal and by when is unclear, but what is certain is that the politics surrounding coal are highly contested and likely to keep changing in a way unfavourable to the industry.

5.2.2 Collie's exposure to carbon pricing

Collie's current coal-combustion activities are significantly exposed should a carbon tax or emissions trading scheme be imposed. The coal-fired power stations, combined with the coal and gas–fired Worsley Alumina refinery, emitted a total 12.5mtpa CO2e in 2010,[7] and a further 7.7mtpa will be emitted if Bluewaters 3 and 4, the refurbishment of Muja A-B and Perdaman urea plant go ahead.[8] If we apply a low initial starting cost of $25/tonne CO2e, as was modelled under the CPRS White Paper (Australian Government, 2008), the cost to Collie's coal industry will be around $312 million-a-year at its current size and $512 million annually if all planned expansions go ahead. These figures show why the coal industry is pushing for carbon pricing exemptions and compensation.

5.2.3 Fading confidence in 'clean coal'

Various technologies have been proposed to enable Collie's coal industry to continue while substantially reducing its greenhouse gas emissions. These include sequestering emissions in algae and gasifying the coal and using the resulting hydrogen and carbon monoxide as fuels instead (Tilbrook, 2009c; Logan, 2008). However, the technology given greatest emphasis is carbon capture and storage (CCS) whereby greenhouse gas emissions from coal-fired power stations are captured and stored in geological formations (Department of Industry and Resources, 2007).

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[7] Including Collie A (2mtpa (EPA, 2005b: 6)), Muja C and C (4.8mtpa (Dopheide, 2010)), Bluewaters 1 and 2 (2.6mtpa (EPA, 2005a: 6)) and Worsley (3.1mtpa, including 2.2mtpa from coal (Worsley Alumina, 2008:6)).

[8] Including Muja A and B (1.3mtpa (Collier, 2010)), Bluewaters 3 and 4 (3.1mtpa (EPA, 2010: iii)), Perdaman (3.3mtpa (GHD, 2009e: 9)) and the scheduled Worsley expansion (an extra 0.6mtpa (Worsley Alumina: 2008: 6)).

Despite Rudd's $2.4 billion commitment to CCS, including $100 million-a-year to fund the Global Carbon Capture and Storage Institute (GCCSI) to lead investment in the technology, no commercial-scale coal-fired power station using CCS is in operation or under construction anywhere in the world (Australian Trade Commission, 2010; GCCSI, 2010). In August 2010, the Australian Liberals announced they would cut funding in this area (AAP, 2010). The Liberal State Government also backed away from the previous Labor Government's $10.3 million commitment to the Collie Coal Futures Group, set up to investigate CCS and coal gasification for Collie's coal industry (Dwyer, 2008).

Globally, about 26 CCS proposals (including the $2 billion, 500MW Hydrogen Energy announced for Kwinana, Western Australia by BP and Rio Tinto in 2007) have been cancelled for technical and economic reasons (WorleyParsons, 2009). The difficulty for CCS is that capturing and compressing CO2 increases fuel needs of a coal-fired power station 25–40 per cent, in turn increasing costs; costs are even higher to retrofit CCS to existing plant (IPCC, 2005). Technological development may reduce these costs, but this is not expected to eventuate until around 2025 (Coal Utilization Research Council, 2006).

5.3 Competition from other energies

The majority of Collie coal is used for electrical generation (New Collie Coal, 2010). This market has experienced strong competition since the 1950s, firstly from oil until the oil crisis of 1973; secondly, since 1985, from North West Shelf gas and recently from renewable energies, which the Western Australian Government has pledged will supply 17 per cent of the State's electricity by 2020 (Bennett, 2010). Competition in

energy markets may cause job losses, with subsequent effects on Collie's population, local businesses and services.

While highly aware of the politicization of Western Australia's energy policy, many key informants appeared to have a low level of awareness of the extent that other energies compete with coal. Several referred to Collie's importance in 'keeping Western Australia's lights on', apparently unaware that coal fuels only about 35 per cent of the State's electricity, compared to gas's 60 per cent (DomGas Alliance, 2008; Office of Energy, 2006; ECS, 2010). None mentioned the 2020 renewable energy target and most thought large-scale renewable energy generation would either take decades to develop or would never be able to replace fossil fuels, despite the fact that renewable energy represented 18 per cent of global power production in 2009 and in the same year, global investment in new renewable energy capacity (not counting hydro) equalled investment in fossil fuel generation at about US $100 billion (United Nations Environment Program, 2010).

Given Western Australia's extensive renewable energy resources and current low level of exploitation (five per cent of electricity in 2008–9 (Office of Energy, 2010)), potential for growth in renewable energy is significant. The long-term cost of renewable energy is projected to fall sharply (National Renewable Energy Laboratory, 2002) while even without carbon pricing, the cost of coal-fired electricity is likely to rise because of rising costs of extraction and the trend towards mining deeper and harder-to-get-at seams (Mudd, 2010). Indeed, a 2009 study found that several renewable energy options would be cheaper than gas or coal to meet New South Wale's projected electricity shortfall by 2017 (Rutovitz & Dunstan, 2009).

5.4 Demand for water

Collie residents have strongly criticized the local coal industry's demand for water and subsequent impacts on the local water table and rivers (Tilbrook, 2009a; 2009b). This threat is already damaging five of Collie's essential features including water supplies, rural lifestyle, Indigenous heritage, natural attractions and biodiversity. If water supplies run out, there will also be impacts on Collie's industries, jobs, population and local services.

The coal industry affects water supplies and water quality in Collie in two ways – firstly through the need to dewater (pump groundwater out of) local aquifers in order to allow open cut mining to occur, and secondly through use of water in coal-fired power stations as cooling and steam (DoW, 2009; D'Rosario, 2010). Under various State laws, the first priority for 'dewater' is the local power generation industry (DoW, 2009). Leftover dewater is pumped backed into rivers, but residents complain that it is not enough to prevent severe damage to rivers including lowered river levels, acidification through the exposure of acid sulphate soils and biodiversity loss. A key informant who has held a strong interest in the biodiversity of Collie's rivers over many decades said that the proposed new power stations and the Perdaman plant would make things worse:

> The environmental impacts of industry on our quality of life as I have known it, the impacts on the river, are there to be seen now. They won't go away. I think the impacts are going to become significantly worse.

According to the Department of Water (2009), industrial abstraction has caused groundwater levels to fall by a metre across the whole Collie Basin and by 50m in some areas. The Department warns that the total 49 gigalitres (Gl) of water a year that

Wesfarmers Premier Coal and Griffin Coal are licensed to dewater from the Premier sub-basin is "highly unsustainable" and 2,000 times what it would be if based on the natural recharge rate (DoW, 2009: 23).[9] This matches the CSIRO's warnings that combined with climate change, industrial demand will cause groundwater and surface water deficits in Collie by 2030 (CSIRO, 2009b).

As shown in Figure 15, the amount of water available for industry from dewatering will only just meet demand until 2021 under the optimum projection. But if the amount of dewater is lower than expected, demand will exceed supply. Implicitly matching the resilience approach of incorporating redundancy to allow for uncertainty (Walker & Salt, 2006), the Department recommends assuming only 70 per cent of the water available under the optimum scenario will be available (DoW, 2009).

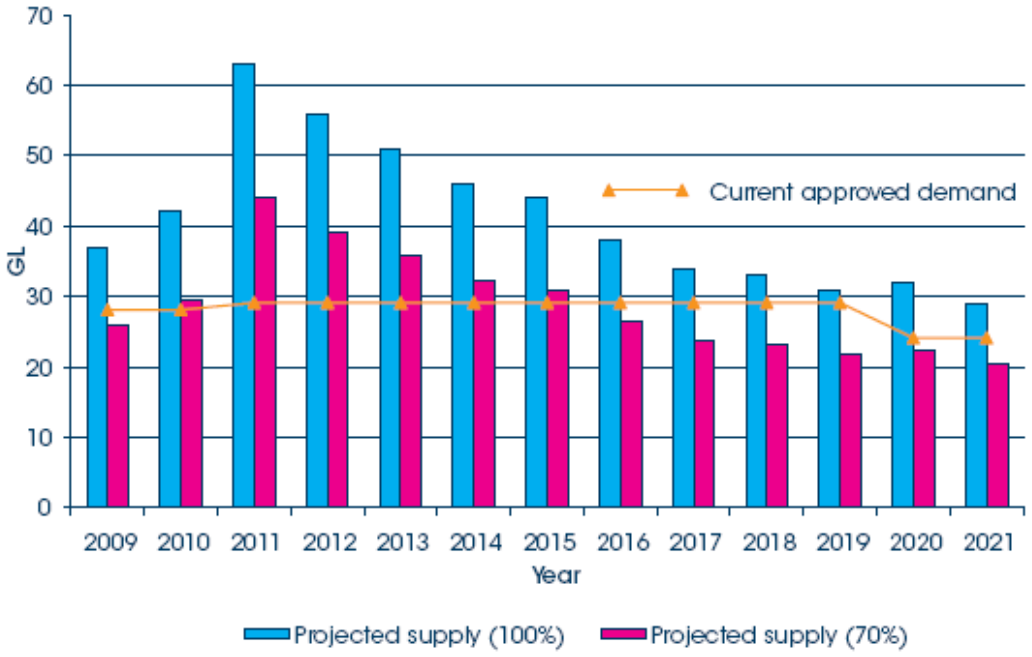

Figure 15. Projected annual mine dewater supply and demand (DoW, 2009)

[9] A gigalitre is one billion litres.

Muja C-D and Collie A power stations, owned by Verve, rely on dewater and licensed bores in the Collie Basin groundwater area for 12–14 gigalitres annually (DoW, 2009). However, it is unclear how Verve's future extra demand will be met once the Muja A-B power stations are reopened (DoW, 2009: Dopheide, 2010). Meanwhile, Griffin Energy's Bluewaters 1 and 2 power stations receive about 6.5 gigalitres annually from dewatering but it is also unclear where Bluewaters 3 and 4, if built, will derive their extra water from, and also how Bluewaters 1 and 2's needs will be met if less dewater is available than under the optimal scenario (DoW, 2009).

Perdaman requires 12 gigalitres-a-year for its proposed plant and has applied to receive this from Wellington Dam (GHD, 2009b) but this plan was opposed by some key informants who felt the dam should be used for drinking, horticulture and recreation.

In addition to questions about how industry will meet its water needs, there are serious concerns about how future water deficits will affect Collie's aquatic biodiversity. The Department says there is insufficient information to understand the impacts of falling water levels on fish, tortoise, marron and groundwater-dependent ecosystems (DoW, 2009).

5.5 Concerns about air quality

Reduced local air quality as a result of future industry expansions concerned several key informants. Despite some research to date (for example, GHD, 2009c; DEC 2008a; 2008b), scientific information about local air quality and impacts from industrial emissions in Collie is incomplete and unsatisfactory. However, this issue has the potential to impact Collie's rural lifestyle, sense of place and natural attractions and in the worst case, affect population stability and local services if people believe their health is threatened and leave.

US research has shown that pollution caused by mining and burning coal contributes to heart disease, cancer, stroke and chronic respiratory disease (Shearman, 2010). Particulates under 2.5 micrometers in diameter (PM2.5) are particularly dangerous because they penetrate deeper into the lung than larger particulates (PM10). Sulphur dioxide emissions also cause respiratory problems if at high levels (National Pollutant Inventory (NPI), 2010).

Sulphur dioxide and PM2.5 emissions self-reported by Collie's coal industry are high in comparison to those reported by the similar industry in Singleton and Muswellbrook, New South Wales, where a government inquiry was announced in April 2010 following public concern about the emissions' impacts (NPI, 2010; Sneddon, 2010).

Table 2. Collie and Hunter Valley emissions (NPI, 2010)

Total annual emissions from coalmining and coal-fired electricity generation†	**Collie**	**Singleton**	**Muswellbrook**
Sulphur dioxide (kg)	56,006,100	1,900,000	120,061,000
PM2.5 (kg)	3,603,000	1,123,000	2,060,000
PM10 (kg)	11,300,000	34,140,000*	18,700,000*

†Emissions are mostly from electricity generation except where indicated by *.

Naturally, the extent that industrial emissions are a hazard depends on how they are dispersed in relation to human settlement. Collie's coal mines and power stations are east of Collie, and prevailing winds in summer are from the east-south-east, indicating

that concern about local health is warranted (Department of Environment and Conservation Western Australia (DEC), 2008b). Several key informants said that because Collie is in a valley, emissions are captured where people live.

A series of reports on Collie's air quality completed in 2008 and released by DEC mid-2010 suggests that the main threat to air quality is wood heater use (DEC, 2008a; 2008b). Yet some of the reports' findings and recommendations show concern about current and future industrial emissions. For example, the report on particulates recommends that "measures are implemented to reduce community exposure to particles" (DEC, 2008b: 7); for further tests to be done to assess the chemical composition of the particles; and for monitoring of PM2.5 and PM10 to continue. However, the DEC monitoring station installed in 2008 only measures PM10 and there is no mention of chemical analysis being done (DEC, 2008b).

The particulates report is based on data collected January 2004–December 2007. In April 2007, Muja A-B were closed, but were re-opened in mid-2008 and ran until April 2009 as a result of the Varanus Island gas crisis. Griffin Energy's Bluewaters 1 power station began operations in late 2008, while Bluewaters 2 began operations in early 2010. This raises the question of what were the industry's cumulative emissions during late 2008–April 2009 when Muja A-B were in operation at the same time as Bluewaters 1, and in the period since both Bluewaters 1 and 2 began operating. Given the report states that World Health Organisation standards for PM10 and National Environment Protection (Air Quality) Measure advisory standards for PM2.5 were breached on several occasions (DEC, 2008b: 14; 15; 24), it seems likely that further breaches of these standards have occurred.

The Rural Action Group (RAG) in Collie has complained to the EPA about factual errors in Perdaman's air quality data and warned the proposed plant would cause

unacceptable effects relating to noise, emissions, water consumption and health and safety risks (RAG, 2009). Despite this, the plant received Federal approval in September 2010 (Perdaman Industries, 2010b). At time of writing, RAG is conducting its own risk assessment on air quality, dust and ammonia storage in relation to the Perdaman proposal and further decisions by Perdaman's investors are pending.

5.6 A finite resource

Williams (1979: 156) warned that Collie coal was finite, "a wasting resource" and that one day, "the sun must sink for Collie the coalmining town, because that is the nature of mining". He quoted a Mines Department's estimate of Collie's extractable reserves of 400 million tonnes, and thinking production would increase to 8mtpa in the 1980s (which it didn't), he calculated another 50–60 years left of coalmining.

Today, the Department says total coal resources in the Collie Basin are 830 million tonnes, including recoverable reserves of around 300 million tonnes (Gregory, pers. comm., 2010). Although further exploration could increase reserves, viability of extraction will depend on costs. While some of the machinery used in Collie's open-cut mines is powered by electricity, there is a heavy reliance on diesel, with a single dump truck's 4,000-litre fuel tank required to be filled daily, according to a key informant who works in coalmining. A global oil price rise is therefore just one factor that could make a big difference to the viability of future coal reserves.

The Department projects future coal production at Collie will be 6–12mtpa, with the upper range reliant on Bluewaters 3 and 4, Perdaman's urea plant, coal exports and the expansion of Muja A-B going ahead (Gregory, pers. comm., 2010). Calculating these figures against the current known extractable reserves, there are 25–50 years left of Collie coal, a projection that matches Williams' 1979 outlook.

A 25–50 year projected lifespan for the Collie coal reserves[10] is not dissimilar to the projected lifespan of proposed new coal-fired plants in Collie, including 30 years for the Bluewaters power stations (EPA, 2010: 3), 10–15 years for the refurbished Muja A-B plants (Dopheide, 2010) and 25–40 years for Perdaman's plant (Perdaman, 2009d). Given these companies are likely to have considered extractable reserves in their investment decisions, it seems that a 30–35 year life span for the industry as a whole seems realistic, taking into account reserves, but without factoring in potential higher costs for extraction or pollution.

Figure 16. An electric-powered digger dumps overburden into dump truck at one of Collie's mines. Author's photo.

[10] Not counting estimated coal resources at Wilga, 30km from Collie (264 million tonnes), and Boyup, 45km from Collie (60 million tonnes) (Gregory, pers. comm., 2010).

When asked if they believed there was a limit on Collie coal's industry, many key informants calculated 50 years with some more generously suggesting 100 or 150 years. A few considered 20–30 years realistic. There is uncertainty as to how long Collie's coal industry can last based on a finite resource yet as Williams noted (1979: 156), "the logical conclusion" is that coalmining will end at some point.

5.7 Regime shift

Other threats to Collie associated with coal that can be briefly touched on here are Collie's changing demographics and work patterns; future oil scarcity; and the encroachment of coal mines on private property as the mining footprint expands (several key informants have been required to move house or are experiencing pressure to do so, while others are annoyed by night time noise from mining trucks).

Yet just the threats described here alone clearly point to worsening conditions for Collie if it continues to expand its current structure as a vertically integrated, coalmining economy. It is clear, as a minority of informants stated, that Collie needs to diversify its economy and not just by finding new ways to use coal.[11]

There does not appear to be any evidence that Collie is at risk of a regime shift in the immediate (two to three year) term. The town remains close-knit, people retain a strong sense of place, the natural attractions, heritage values and rural lifestyle are still present and local services, population and employment prospects are stable or buoyant. No key informants claimed that reduced air quality was affecting them currently – it was mainly future emissions that concerned them. However, there is clear evidence of

[11] At 3.4mtpa of greenhouse gases, Perdaman's urea plant – considered by some informants as diversification of the economy – will emit more than twice as much CO2e as one Bluewaters power station (1.5mtpa), meaning it will also be vulnerable should carbon pricing be introduced.

damage to Collie's groundwater supplies and river health having already occurred, and the outlook for these is severe.

Collie's trajectory towards further expanding its coal industry, including increased dependence on coal for maintaining employment prospects, population and economic vitality, is alarming as the evidence indicates that this industry has at best a 40–50 year life. Further, other trends indicate that 40–50 years is overly optimistic and a near term timeframe of 10–15 years is more accurate. These trends include the likely imposition of carbon pricing and other greenhouse gas mitigation policies, future oil prices rises (affecting the cost of coal extraction) and increased competition from renewable energies – not to mention severe problems for the amenity and environment of Collie as groundwater goes into deficit and potentially, loss of local air quality.

The above timeframes are necessarily partly guesswork because many of the threats are volatile, such as highly politicized Government energy policy and energy markets. The challenge is therefore how best to plan for an inevitable transition in Collie's economy that will occur within a relatively uncertain, although certainly not distant, future.

Chapter 6: Collie's capacity to adapt

Chapter 4 showed that Collie coal is in the late stage of a conservation phase of an adaptive cycle and has already experienced two small collapses in 1960 and 1994. Chapter 5 explored threats that point to further, possibly greater decline in the industry in the near to medium term. This poses the question, how well equipped is Collie to adapt to such a change without losing essential structures and functions? Release phases usually entail loss of natural, social and/or economic capital but it may be possible to manage the transition gracefully if correct measures are taken (Walker & Salt, 2006). As one key informant involved in civic leadership said:

> Collie needs to plan for how it will survive beyond coal. It didn't transition particularly well in my opinion from underground mining to open cut mining.

This chapter examines Collie's adaptive capacity in relation to future shock in the coal industry, drawing on lessons learnt from other Western Australian towns in transition as well as resilience theory and interviews with key informants.

6.1 Lessons from other towns in transition

Haslam-Mackenzie's 2009 analysis of Exmouth following the US military withdrawal in the 1990s and cuts to the logging industry in Manjimup from the late 1990s provides the following insights into community transitions:

- Small, isolated, single industry-dependent towns suffer more from industry closure than large, connected communities with diversified economies;
- Certainty and advance warning aids transition;

- Partnerships between State and local government can be beneficial but rushed decisions and stop-gap measures delay recovery;
- Care must be taken to ensure assistance goes to people committed to staying in the area;
- Any influx of newcomers should be managed to ensure community diversity and appropriate services;
- Maintaining community confidence is essential;
- Tourism may partially replace heavy industry as an economic driver but must be developed strategically. (Haslam-Mackenzie, 2009)

Collie's population is more than double Exmouth's prior to transition and its economy is already fairly diversified: only a fifth of working residents are directly employed in coalmining and coal-fired power generation and the other most common industries of employment are school education, manufacturing, cafes, restaurants and takeaway food services (Haslam-McKenzie, 2009; ABS, 2007a). Many of the coal industry workers live outside Collie, so the effects of unemployment will be distributed to other towns. However, key informants suggested many businesses supplied or serviced the coal industry, and shops depended on big spending by well-paid coalminers.

The five-year notice given by the US military of its phased withdrawal gave Exmouth opportunity to plan ahead in conjunction with State Government agencies (Haslam-McKenzie, 2009). Empty houses were sold in tranches by a trust, with homes awarded to people committed to staying in the area and able to add skills and demographic diversity. Funds went to community and infrastructure development.

In contrast, in Manjimup, energy and time was absorbed in fighting policy changes, leading, when the changes were implemented, to rushed decisions to appease media and political pressure (Haslam-McKenzie, 2009). Assistance went to people who later left or lived outside the area and a big influx of social housing tenants from elsewhere caused community dislocation and anti-social behaviour.

Collie's situation bears greater resemblance to Manjimup than Exmouth in terms of uncertainty and disagreement surrounding coal's future. There is a risk that Collie people will exhaust their time and energy seeking protection of the industry, rather than planning for inevitable transition, with the result that the transition is badly managed. A precedent can be seen in Collie's fight in the 1980s and 1990s to supply base-load power – in the end, coal won the power contract but despite this, many jobs were lost nine years later in the switch to open-cut. Because Collie's leaders had focused on lobbying Government to give Collie the new power station, little attention was given to preparing Collie's response to the slow and predictable trend of increased mechanization and job cuts.

Haslam-McKenzie (2009) notes that tourism is often viewed over-simplistically as a replacement for heavy industry but it provides little employment or net gain unless it combines with other business enterprises in a complementary way to boost commercial activity. For example, tourism targeting young visitors and eco-tourists will attract young residents and new businesses and services will develop to meet needs of young families. This comment seems pertinent to Collie, which has abundant natural attractions and sporting facilities to appeal to young people and is a two-and-a-half hour drive from Perth. Surprisingly, a world-class hiking attraction, the Bibbulmun Track, which runs from Perth to Albany, bypasses Collie by 2.7km, although it passes directly through other South-West towns, meaning hikers do not generally stop in

Collie (Bibbulmun Track, 2010). Collie also lacks hostel-style accommodation (Collie River Valley Visitors Centre, 2010). Although considerable effort has been made to promote tourism since the late 1990s, it appears that there may be opportunities to increase tourism in Collie in a complementary manner with other enterprises.

Figure 17. Local produce at Collie's Sunday market. Author's photo.

Figure 18. Nature tourism in Wellington National Park. Author's photo.

6.2 Attributes of adaptive capacity

The following list of Collie's adaptive capacity strengths and weaknesses draws on attributes identified by Walker & Salt (2006), Folke et al. (2002) and Levin (1999) (see Chapter 2.4).

Diversity

Diversity ensures that even if one part of a system fails, other parts still function and it also provides options for doing things differently in the future (Walker & Salt, 2006). Most key informants felt Collie should increase its economic diversity. Some said Perdaman's proposed $3.5 billion urea plant was a good example of diversification but

others said it would simply extend dependence on coal. Other ideas to diversify Collie's economy included: renewable energy such as a solar thermal farm; local manufacturing (adding to two existing machinery manufacturing firms); horticulture (for example, stone fruit); and tourism.

Others called for greater diversity of services, including health, youth, disability and cultural services. Several female informants involved in local community and business groups complained Collie had good sports facilities but few cultural activities and a promised shire art gallery would only be a "cheap and cheerful" version. Three informants who were parents or grandparents expressed strong concern about the lack of activities for young people, who were turning to petty offending and substance abuse.

Social diversity was a concern: many informants described the ageing, dwindling membership of volunteer groups. Some blamed 12-hour industry shifts, others blamed a lack of people aged 30–45 caused by the 1990s job cuts forcing young people to leave and others highlighted the high number of retirees drawn to Collie by cheap housing. One informant involved in civic leadership said that Collie lacked gender, age and ethnic diversity in its governance organisations such as the Shire. New industries would attract new people with different skills, which would improve local decisions:

> The strength of the decisions you make is in the diversity and breadth of the consultation and the demographics and the backgrounds of all the people who are involved.

Awareness

Awareness of, and willingness to do something about, slow variables such as a dwindling resource or accumulating pollution problem is essential if the problem is to

be solved (Walker & Salt, 2006). About half the key informants acknowledged human-caused climate change as a problem, with the remainder expressing uncertainty rather than complete disbelief. A miner said:

> I am not even sure if I believe in it and then I am not sure if my thoughts are that way because I am only protecting what I do.

Most informants were aware of the severe outlook for water supplies. However, pro-coal industry informants were less aware, with one informant well-placed to advise both industry and community members about industry matters surprisingly ignorant of Perdaman's plan to take 12 gigalitres from Wellington Dam.

Informants' views on Collie's degree of vulnerability varied markedly. A slight majority considered Collie coal's future assured for the medium to long term (50–100 years), mostly on the basis that no alternative energy source had been developed but about a third felt that Collie coal faced serious significant threats within 10–15 years. A striking number had a low level of awareness about the degree to which gas has replaced coal already as the main source of Western Australia's electricity, few seemed aware of the growth of renewable energies worldwide and none made reference to the State Government's 17 per cent renewable energy electricity by 2020 target.

On dwindling hope in clean coal technology (see Chapter 5.2.3), some pro-coal informants expressed determination (for example, "Where there is a will there is a way"), while others dismissed it as a near-term solution.

Several key informants, including those in governance and community leadership roles, commented that Collie's civic leaders, Shire or community in general, were too apathetic or ignorant to plan ahead:

> People are a little bit set in their ways. They see Collie as a coalmining area and they are a little bit slow to take up the idea that there are other things we can do and diversify into.

Views about Collie's vulnerability did not necessarily align with people's level of support for coal. One pro-environment informant believed nothing would stop industrial expansion whereas a pro-industry informant feared for the industry's immediate future. This divergence of perspectives indicates a need for greater information-sharing and debate, as one informant with a long involvement in local government recommended:

> There's a lot of people who don't understand it … there needs to be a lot more discussion on what the future is going to be in regards to energy.

Redundancy

Redundancy, or 'slack', rather than exploiting resources to their limits, enhances resilience because it provides a buffer for unexpected events (such as worse rainfall decline than projected), as well as ensuring opportunities for renewal and reorganisation (such as sufficient water available to supply alternative industries).

About half of the key informants expressed concern that Collie was nearing its limits in terms of water supply, air quality and amenity. Most people blamed mine dewatering (and to a lesser extent, reduced rainfall and dredging of river banks in the 1960s) for the poor state of Collie's rivers. For example, one long-term landowner said:

> We have cracked the ground; we don't have a river.

Others expressed concern at the proximity of Griffin Coal's Ewington mine to town and resulting noise, as well as cumulative effects of the industry, including the following informant whose partner worked in a power station:

> People are wanting to put a limit, a ceiling on it. … This one (Perdaman) might be the one that pushes us over in terms of air, noise, mining being close to town.

Commenting on the reduced annual rainfall and climate change, another informant with a background in local government called for a precautionary approach, in line with resilience thinking (Janssen, 2002):

> I don't care whether it's climate change or not. I'd rather go the middle road and say 'oh well, it's probably a bit on both sides but let's be careful'.

While a small number of the informants appeared to support a gradual transition from coal to other industries, no one called for the industry's complete closure. A common view expressed by an informant with a background in youth work was:

> You don't actually want to get rid of it; you just want to limit it.

Modularity

Over-connected systems are less resilient to shocks because every component is connected to everything else; in contrast, modularity and self-sufficiency enhance resilience (Walker & Salt, 2006). While Collie has a good range of essential services, in the past it was more self-sufficient, supplying its own dairy, horticulture, bread and meat needs (Bird, 2010). However, while Collie appears to have a strong sense of place and rich heritage of self-sufficiency, its civic leaders have long seen Collie's success as dependent on coal. This was demonstrated by some key informants using the words

"the community" or "Collie" interchangeably with the coal industry. For example, one coal industry-based informant said:

> There's always been a strong relationship with the government to deal with issues impacting in the community, especially issues beyond the control of the community.

Another informant involved in civic leadership said:

> Collie really hinges on what the world is going to do; we can't look at it in isolation any longer.

The solution to cross-scale threats beyond Collie's control was seen by both of the above informants as government intervention: a precedent established from the industry's outset and seen very strongly during the fight for a coal-fired power station in the 1980s (see Chapter 4). This reflects the non-modular nature of Collie's coal industry. In other words, the widely held view in Collie that the community depends on the coal industry is linked to a belief that government should favour coal over other energies for the sake of the Collie community – as opposed to helping Collie ease itself off coal dependency. However, one informant involved in civic leadership bucked the trend with this comment:

> We need to actually start having someone at a State or Federal government level committing money to the process to start the pilot process off. Whether that's 50 or 100 million dollars to establish a pilot solar panel farm or a wind farm or whatever, that's what needs to happen.

Innovation

Industries in the late conservation phase of an adaptive cycle are less resilient because they are driven by the need to be increasingly competitive, meaning they turn to larger

economies of scale or specialize, as well as seek protectionist policies – thus preventing newcomers from joining and discouraging innovation (Walker & Salt, 2006). The Collie tradition of mine jobs being passed from father to son was seen by some informants as contributing towards a warm, family feel to the town, but an Indigenous informant complained that it ruled out potential jobs for Indigenous people, while an older female informant observed:

> It was always hard for the girls, they never got employment.

On the other hand, innovation is not necessarily beneficial: many informants complained about the trend towards employing outsiders, rather than Collie residents, in Collie's coal and alumina industries. This trend created a missed economic opportunities for Collie as well as mismanagement and workforce dislocation at Griffin Coal because newcomers were unfamiliar with the mine and at crib, locals and outsiders sat separately.

Others noted that the declining number of jobs in coal for locals contributed towards greater unrest about industry impacts. Pro-coal industry informants saw these "Not in My Back Yard" (NIMBY's) as a problem:

> If you are not directly linked to the coal industry then the wave starts to build. You get this sort of resentment.

But others saw them as positive, with an informant employed in a coal-related industry noting:

> Collie has very much been a town that knows where its bread it buttered and has sort of pushed those issues to one side because we all depend on them for our jobs. ..But you are starting to see a few more groups come out and talk about things like that.

Social capital

Trust, strong networks and leadership enable human actors in a system to respond effectively to change (Walker & Salt, 2006). Collie residents are strikingly hospitable and friendly. There also is a high level of community connectedness, demonstrated by residents fundraising for neighbours when hard times hit.[12] Several key informants who had moved to Collie from elsewhere cited community as an attraction, with one stating:

> The thing that brings people here is jobs; the thing that keeps them here is community.

The Shire of Collie is also keen to promote and encourage this positive attribute, noting in its strategic plan that there has been resurgence of social capital in Collie's community (SoC, 2008). Many informants seemed proud of Collie. One involved in promoting the coal industry stated:

> We bounce back; we are a very resilient group. ... Families here have had generation after generation that have worked in the coal industry and that's what brings out resilience because there is a lot of mum, dad, grandfather relationships in the town and that helps to sort of get people through. … I think there is a lot of respect for the town itself.

As Walker & Salt (2006) note, strong social ties can be counterproductive by making it hard for people to innovate, but they can also be positive, enabling people to work together as a community towards a shared goal.

[12] For example, 45 donation tins were distributed around Collie after two local children killed in a highway crash (Strike, 2010).

Figure 19. Raffle ticket sales for local causes are a common sight in Collie. Author's photo.

Chapter 7: Perverse resilience in Collie

Ráez-Luna (2008), Albrecht (2010) and Evans (2009)) have identified perverse resilience as a major problem in social systems, especially in relation to fossil fuel industries. This chapter investigates evidence of perverse resilience in Collie.

Just as 'resilience' is a normative concept and requires defining in terms of 'resilience of what' and 'for whom?' (Lebel et al., 2006), whether something is perversely resilient depends on one's standpoint. However, from a sustainability perspective, we may say that perverse resilience describes persistent forms and functions that cause human or ecological suffering (Myers & Kent, 2001).

Ráez-Luna (2008: 326) writes that perverse resilience typically involves "locked systems (that) preclude creative change (and) enhancement of human spirit"; thus perverse resilience might include functions or structures that block or undermine adaptive attributes such as diversity, innovation, awareness, trust and leadership. Evans (2009), following Ráez-Luna (2008), notes that perverse resilience is characterised by unequal flow of benefits and opportunities.

7.1 Unequal benefits and opportunity

Ráez-Luna (2008) argues that the third world suffers because of perversely resilient structures that concentrate wealth in the first world; the third world is often stuck in the weakly-organised exploitation and early conservation stages of an adaptive cycle, while the first world enjoys the accumulation of capital and stable regulation typical of the

conservation stage.[13] Evans (2009) finds a similar hegemony exists in the Hunter Valley, where global corporations accumulate wealth from coalmining while leaving damaged natural and social capital in their wake, including air pollution, poor health outcomes, community disintegration, loss of Indigenous heritage and destruction of rivers and ecosystem health:

> Enormous wealth is being appropriated from the Hunter Valley, but significant environmental and social engineering is required to maintain an illusion of ecological and social sustainability. The region's resilience is thus perverse rather than genuine. … Genuine sustainability cannot be achieved if the resilience of one community, corporation or country is achieved by undermining the resilience and sustainability of other people or places. (Evans, 2009: 128)

While Collie coalmining is conducted on a smaller scale and is primarily for domestic markets,[14] Evans' theme is echoed in Collie. In Collie, rivers and groundwater supplies are being sacrificed for industry along with biodiversity, Indigenous heritage, rural lifestyle and potentially, local air quality. Loss of natural capital means lost economic potential: alternative industries such as tourism and horticulture require water and healthy rivers. To date, the most obvious harm caused by the coal industry to Collie's essential features is to local rivers and groundwater supplies through dewatering and industrial demand for water. The fact that the same industry is a significant contributor to global climate change, which has caused reduced rainfall across the South-West and is partly responsible for the catchment's poor health (CSIRO, 2009a), is further

[13] Ráez-Luna calls the exploitation stage 'renewal' and conservation stage 'growth' (Ráez-Luna, 2008).

[14] Wesfarmers, which owns Wesfarmers Premier Coal, is a large Australian listed company while Griffin Coal, in administration at time of writing, was part of the privately-owned, wholly WA-based Griffin Group.

perversity – what some might call a vicious circle, or "maladaptive" cycle (Holling et al., 2002: 95).

Other examples of perverse resilience include:

1. Following on from the clearing of State forest in 1986 in order stockpile coal that no longer was needed (see Chapter 4.6), Griffin is, at time of writing, seeking approval to clear 1,700ha of State Forest for its Muja South mine extension (home to endangered and vulnerable birds and mammals and a critically endangered spider orchid). A decision is also imminent on clearing 46ha of bush for Perdaman's urea plant, on land inhabited by endangered Carnaby's black cockatoo and other mammals listed as vulnerable (Griffin Coal, 2009; GHD, 2009a). This contrasts with a Government sign at Collie's Harris River Dam, urging the public to protect the cockatoos against threats including "destruction of forests".

Figure 20. Black cockatoo sign, Harris River Dam. Author's photo.

2. Residents living in two of Collie's outlying settlements, Cardiff and Collie Burn, are banned under the Shire planning scheme from improving their properties by building farm chalets or livestock sheds (Tilbrook, 2008). This rule, introduced in the latest scheme, aims to stop land values going up because the land is earmarked for future mining and will eventually be resumed. A key informant from one of the settlements said that the Cardiff community hall, used as a meeting place since 1928, was only saved from being closed by the Shire because of community protests. This contrasts with the Shire's *Strategic Plan* which enthuses about the importance of community, states that a strong economy is a diverse economy and cites promoting tourism as a strategic goal (SoC, 2008).

3. As a key informant involved in local amenity improvements and health commented: "Collie hasn't got a lot to show for it being such a prosperous town". While efforts to improve local infrastructure are obvious, some facilities, such as the outdoor pool, closed several months annually, and part of the Collie CBD, appear in need of an upgrade. The situation results partly from the fact that 75 per cent of Collie shire is State forest and non-ratable, but inadequate Shire funding is made worse by State Agreement Acts passed in the 1980s that exempt the mines and publicly-owned power stations from paying Shire rates. An informant with a background in local government explained that although the Shire has managed to ensure that Griffin's Bluewaters plants will pay rates, most of the industry does not:

> Muja Power Station, Collie A and Worsley Alumina and the mining companies, you get nothing out of them at all. All you get from the mining companies … is the coalmining leases that are not being used.

The informant noted that the mining companies had recently made generous community donations, including $35,000 from Wesfarmers Premier Coal towards Collie

Visitors Centre. However, she said this was only a fraction what it would have spent on shire rates.

7.2 Undermining adaptive capacity

Ráez-Luna (2008) notes that in the human world, as opposed to ecosystems, individuals and institutions work consciously to control outcomes. In Collie, this dynamic may have had the harmful effect of undermining the aspects of Collie's adaptive capacity identified in Chapter 6.2. Specific tactics used by institutions are listed here against the type of adaptive capacity they appear to have undermined.

Fostering uncertainty (versus Awareness)

Vested interest groups foster uncertainty about science in order to maintain the status quo (Gunderson & Holling, 2002). Oreskes & Conway (2010) have shown how this tactic has been widely used by the tobacco industry to counteract scientific evidence that smoking is bad for health. As Oreskes & Conway (2010), Monbiot (2006), Hamilton (2007) and Pearse (2007) have also shown, some of the same individual lobbyists, public relations professionals and organisations funded by the tobacco industry to discredit scientific evidence on smoking, have also been paid by the fossil fuel industry to discredit scientific evidence that climate change is occurring. One such group, funded by tobacco firm Philip Morris, was the US-based The Advancement of Sound Science Coalition, which aimed to educate media, public officials and the public about junk science (Hamilton, 2007). This Coalition is no longer active and has been superseded by the Heartland Institute, an organisation that questions both climate change science and evidence that smoking is harmful (Heartland Institute, 2010). The Heartland Institute

has funded publication of 150,000 copies of a booklet criticising climate change science written by Perth-based writer Joanna Nova, who addressed a public talk in Collie in November 2009 where she distributed free copies of her booklet (JoNova, 2009).

In another example of how global campaigns targeting policy outcomes on climate change and energy have reached Western Australia and thus may have implications for Collie, a report by Alvarez et al. (2009), *Study of the effects on employment of public aid to renewable energy sources,* concluded that the large-scale uptake of renewable energies in Spain had caused net job losses. In September 2010, a digital version of the report by Alvarez et al. was emailed by a staff member at a large Western Australian Government-owned energy organisation to a Western Australian journalist who specialises in writing about energy issues for Western Australian audiences. [15] In the same month, a senior manager of another Western Australian Government-owned energy organisation recommended the report to a representative of a Western Australian not-for-profit group promoting renewable energy. It is likely that the individuals who forwarded and recommended the Alavarez et al. report were unaware of the controversy about it. In March 2010, Greenpeace had released a study highlighting Alvarez et al.'s report as being funded by Exxon Mobile and Koch Industries, oil companies which Greenpeace claims together spent US$34 million funding climate science denial groups globally in 2005–2008 (Greenpeace, 2010). Amongst other criticism of Alvarez et al.'s report, a review by the US National

[15] In September 2010, a Western Australian journalist who is known to the author recommended and forwarded the report by email to the author on being forwarded it by a staff member at a large Western Australian Government-owned energy organisation. Also that month, a representative of a not-for-profit group promoting renewable energy, of which the author is an active member, revealed to the group that he had been recommended to read Alvarez et al.'s report by a senior manager of another Government-owned energy organization. The names of the individuals and organizations are omitted here for privacy reasons.

Renewable Energy Laboratory, a division of the US Department of Energy, had earlier found that the report's primary conclusion (that the uptake of renewable energies cost net job losses in Spain) was not supported by the contents of the report (Lantz & Tegen, 2009).

Lobbying politicians to maintain status quo (versus Innovation)

Pearse (2007) has described how high-polluting companies who lobbied the Howard Government later claimed credit for the Government refusing to sign the Kyoto Protocol. Long (2010) has argued that the political power of large mining firms in Australia continues unabated, with former Prime Minister Rudd's political demise attributable to some extent on these firms' response to his attempt to tax their super-profits. As seen in Chapter 4, over the history of Collie's coal industry, its members and Collie's civic leaders have sought government assistance when the coal industry has been in difficulty and this appears true today. For example, a key informant involved in supporting the interests of the coal industry described the need to make "stronger representation to government" to secure support for 'clean coal' research to reverse a recent cut in funding.

Corporate donations to extend community tolerance (versus Redundancy)

Donations to the arts, sport and charities have long been employed as a public relations tactic by the tobacco industry to improve its public image and build a constituency of support (Saloojee & Dagli, 2000; Trochim et al., 2003). Similarly, Beder (1997) has shown how the same tactic, known as 'strategic philanthropy' in the public relations industry (Kim & Reber, 2008; Heath & Ni, 2009), has also been used by polluting industries to counteract opposition to environmental harm.

In 2008–9, Wesfarmers spent $388,000 on community organisations in Collie including supporting educational programmes, sports, festivals and the Visitors Centre (Wesfarmers Resources, 2009). Perdaman has hosted a cricket clinic in Collie, is supporting local cricket and rugby players and has funded Collie high school students to attend a Perth science competition (Perdaman Industries, 2010c). Amongst many other donations made by members of Collie's coal industry to community activities and wellbeing in Collie, these payments have provided useful benefits to the people of Collie. However, as Evans (2009) warns in regards to the Hunter Valley, owing to the current paucity of information about potential impacts on air quality and health from the coal industry in Collie and the dire state of Collie's rivers, it is not clear whether these benefits outweigh the negative impacts of industry. As one key informant with a background in local government commented (see Chapter 6.2), there appears to be a need for greater information-sharing and debate about the relative costs and benefits of different energy policies in relation to Collie.

Perverse subsidies (versus Feedbacks[16])

Including diesel rebates and public infrastructure construction, direct and indirect subsidies to Australia's transport and stationary energy sectors amounted to $10 billion in 2005–6, including to $1.1 billion to coal-fired electricity producers who made less profit than that in the same year (Riedy, 2007). A net economic loss (measured simply in profits and not even counting currently uncosted externalities such as greenhouse gas emissions and other environmental and social impacts) is perhaps the ultimate economic perversity, since taxpayers are the losers. As explored in Chapter 5.2.3, the

[16] Omitted from Chapter 2.6 for space reasons, feedbacks boost adaptive capacity by signalling problems thus helping a system to self-correct (Walker & Salt, 2006). Subsidies, especially indirect ones, mask feedbacks.

Labor Federal Government's $2.4 billion commitment to carbon capture and storage is another enormous subsidy to coal that does not appear likely to reap equal economic return and is therefore perverse.

Royalty addiction (versus Modularity)

Evans (2009) argues that the New South Wales Government is addicted to the royalties it receives from the Hunter and Gunnedah coal basins, which he claims creates a political reluctance to scale down the industry. Although royalties to the Western Australian Government from Collie's much smaller coal industry were just $15–16 million in 2009–10,[17] and dwarfed by those from iron ore mining, even this amount may be hard to give up. Since royalties are justified on the basis that miners remove publicly-owned finite resources, no royalties flow from renewable energy projects, possibly making renewable energies a less popular choice for government than energies based on extracting finite energy resources.

[17] Based on a $2.52/tonne royalty for coal sold domestically (Department of Treasury and Finance, 2009: 1; 2010: 6).

Chapter 8: Learning from Collie

Section 8.1 synthesizes the findings of chapters 4–7 to address the primary case study question, 'how resilient is Collie?' and the secondary question of perverse resilience. Section 8.2 considers the application of resilience assessment to other Western Australian towns.

8.1 Collie's choice

This case study explored how a social-ecological system, Collie, may be assessed for resilience by examining disturbances that may push it into a new regime (Berkes et al., 2003; Walker & Salt, 2006). It used the metaphor of an adaptive cycle to show how resource-based systems experience change over time and it examined attributes that are likely to help Collie to self-organise and transform in response to a future release phase in its adaptive cycle: the closure of Collie's coal industry. Finally, it described the presence of perverse resilience, which undermines adaptive capacity and maintains inequity in wealth and opportunity, thus causing social and ecological harm and missed economic opportunity for renewal.

The study found that Collie is poised to lock into a future based on coal through the establishment of the proposed coal-to-urea plant, mine expansions, the refurbishment of Muja A-B power stations and possible construction of Bluewaters 3 and 4 power stations. The benefits of these expansions will include jobs and boosts to Collie's

population and local services: benefits that Collie residents consider essential to their future. However, an examination of threats to the coal industry indicates that these benefits may decline after 10–15 years with shocks to Collie's coal industry likely to take place around this timeframe. The future of coal is highly vulnerable to changes in Government policy on greenhouse gas emissions and competition from other energies. In addition, an industry based on a finite resource such as coal must end eventually but even before reserves are used up, the rising costs of extraction, limits on water available to industry and growing community intolerance for impacts on local amenity and air quality are likely to make continuing to mine and burn coal in Collie more difficult. If the expansions go ahead, in 10–15 years' time, the condition of Collie's rivers and groundwater will be even more dire; health problems associated with air pollution in the Hunter Valley may also occur in Collie; the shire's rural lifestyle will be marred and potential to promote Collie's natural attractions, biodiversity and Indigenous heritage will have been reduced through the degradation of rivers. Alternative industries such as horticulture, viticulture and tourism, which require water, a clean environment and a clean, green reputation to thrive, will be less likely to establish.

Holling et al. (2002), Allison & Hobbs (2004) and Carpenter & Brock (2008) use the terms 'rigidity trap' or 'lock-in trap' to describe the pathological state of systems where perversely resilient forms exist alongside, or instead of, adaptive dynamics. Such traps are characterised by low potential for change, high connectedness and high resilience (Allison & Hobbs, 2004). They may also exhibit a sunk cost effect whereby even if future prospects are dim, actors replicate past investments rather than trying something new (Janssen & Scheffer, 2004). There are signs of such pathology and perverse resilience in Collie now although the situation is not yet chronic: the rivers and groundwater supplies could be improved if industrial demand for water is curbed. In addition, Collie

has strong social capital and moderate economic diversity and therefore a degree of adaptive capacity that could help it prepare for transition. However, further coal expansions will reduce Collie's future capacity to adapt to inevitable decline in the coal industry.

In the worst case, Collie may become trapped in an increasingly harmful, maladaptive cycle based around coal whereby its economy becomes more and more dependent on one industry and less and less able to diversify. Just as a farmer sacrifices more and more money on fertilizers even though his or her crops are diminishing because the soil is degrading, so may Collie sacrifice more of its assets such as water, rivers, clean air, rural lifestyle, sense of place and heritage for increasingly low economic return, measured in jobs for the community. Through a combination of increased mechanization, open-cut rather than underground mining and a tendency by workers to live outside the shire, the economic return to Collie through jobs in coal has already been diminishing for some time. As noted by Williams (1979), peak employment in Collie coalmining was in 1954, and there has been a steady trend involving both major job cuts and smaller cuts since then.

Collie's resilience is under threat within the near-term: whether it improves its resilience by strengthening its capacity to undergo a future successful transition is a choice for its residents and leaders. A useful first step would be improving awareness and debate at a local level about the future of coal and energy policy and what people want for Collie.

8.2 Applications elsewhere

At time of writing, Western Australia's environmental movement has just begun to focus on a looming boom in greenhouse gas emissions from the State's fast-growing

liquefied natural gas (LNG) export industry. Commonly promoted as a 'clean' fuel,[18] much of the natural gas proposed to be extracted and processed off north-west Western Australia is particularly high in carbon dioxide, which will be stripped from the gas and in most cases, vented to the atmosphere (Appendix 2). This is proposed to occur at new industrial hubs, including at highly controversial locations such as the Barrow Island off the Pilbara (the 'Gorgon' project, now under construction), Burrup Peninsula and James Price Point in the west Kimberley (part of the Browse Basin gas development).

The LNG is to be sold to mostly Asian markets where its proponents say it will displace coal, thus combating climate change (Woodside, 2010). However, the venting of CO2 prior to export (and the emissions caused by energy generation required for gas processing) is rarely mentioned in environmental comparisons of gas and coal. While proposed expansions of Collie coal will alone cause a 10 per cent increase (7.7mtpa) on Western Australian total 2008 greenhouse gas emissions, the total emissions from export LNG projects by Chevron, Shell, Exxon Mobile, Woodside and others will equate to a 78 per cent (58.9mtpa) increase by 2016 (Appendix 2).

As with coal, there are concerns about the finite nature of gas resources. A study for the DomGas Alliance, representing domestic gas users, found that Western Australia's known gas fields are declining and known gas reserves are fully committed under LNG export contracts on terms up to 25 years, leaving a 600 terrajoules-a-day shortfall between potential demand and known new production over the next decade (Economics Consulting Services, 2010). LNG exports are said to have forced up the price of domestic gas, making coal-fired projects more attractive; Perdaman originally intended to use gas (*The West Australian*, 2010; Barker & Bloch, 2010).

[18] See, for example, *Australian Liquified Natural Gas (LNG) – Clean Energy for a Secure Future* (Department of Resources, Energy & Tourism, 2008)

As with Collie, Pilbara and Kimberley communities near to where the LNG hubs are proposed face locking in to a high greenhouse-gas emitting future which will be lucrative in terms of employment and investment for the next 10–15 years but is uncertain after that. The Pilbara Cities Project assumes continued industrial growth for Karratha and Port Hedland but barely addresses the implications of strong greenhouse gas reduction policies or the using up of finite resources (Newman et al., 2010). These are decisions for all Australians to weigh carefully and for Western Australian's northern towns facing further industrialization in particular. Resilience assessment would be a useful tool for this.

Chapter 9: Conclusion

This conclusion summarises the findings in relation to the research aims described in Chapter 1 and recommends areas for further research.

9.1 Key findings

The literature review in Chapter 2 addressed the first sub-aim by exploring resilience thinking as an approach to sustainability assessment, finding that resilience thinking offers useful concepts and metaphors for understanding the complexity of real life situations, including the cross-temporal and spatial scale influences that may push a system from one regime into another. However, it noted that many resilience researchers to date have overlooked a key difference between the dynamics of largely social/human systems such as a coalmining community and purely ecological systems such as a wetland or coral reef: outcomes in ecosystems are not usually determined by the conscious use of power whereas this is often true of social systems, particularly when political or economic interests are at stake, such as in Australian fossil fuels industries (Evans, 2008, 2009; Albrecht, 2010). This means it is essential for researchers examining resilience in largely social systems to declare in whose interests they are investigating resilience and justify this, and that they explore the role power plays in the system being studied (Leach, 2006; Lebel et al., 2006, Ráez-Luna, 2008).

Chapters 3–6 addressed the second sub-aim through a case study of resilience in the coalmining shire of Collie, including an examination of Collie's history, major threats to the coal industry and Collie's capacity to adapt to these threats. The historical analysis found that Collie coal's industry is in the late conservation stage of an adaptive cycle, when systems become increasingly vulnerable to collapse, and it has already had two

minor release phases. Multiple threats to Collie's coal industry were found to include climate change, greenhouse gas mitigation policy, competition from other energies, dwindling water supplies, concerns about local air quality and the finite nature of the coal resource. Combined, these drivers indicate transition will be forced upon Collie's coal industry within the near to medium term: 10–15 years. While this projection is based on fairly volatile variables such as energy markets and greenhouse gas reduction policy and therefore fairly uncertain, an industry based on a finite resource that is increasingly expensive to extract must come to an end eventually. An examination of other Western Australian towns forced to undergo transition showed that planning ahead for transition rather than exhausting energy and time on fighting inevitable change was a better strategy: a lesson that can also be drawn from Collie's history during the 1980s and 1990s, when the Collie community and coal industry focused their efforts on securing a new coal-fired power station instead of preparing for inevitable job losses from the industry as result of increased competition. An analysis of Collie's adaptive capacity found some strengths including moderate economic diversity and strong social capital, however there appeared to be gaps in awareness about the slow variables or trends that would threaten Collie in the near future. This analysis backed a key informant's call for greater debate and information about energy policy.

Chapter 7 addressed the third sub-aim by considering the influence of perverse resilience on Collie. It found alarming evidence of its presence, including the sacrificing of local social, environmental and potential economic capital – in particular the health of local rivers and groundwater supplies – for the sake of maintaining and expanding the coal industry. It also identified functions that are directly undermining Collie's adaptive capacity, such as misinformation campaigns, perverse subsidies, political lobbying and sponsorships that extend community tolerance of environmental harm.

Chapter 8 summarised the case study findings by comparing Collie's position, currently on the cusp of industry expansions, as a choice between committing to a 'lock-in trap' based on coal if proposed expansions go ahead or instead, rejecting the industry expansions and building Collie's adaptive capacity in the face of an inevitable future transition from coal. Chapter 8 also addressed the fourth sub-aim by considering whether resilience assessments should be conducted on other Western Australian communities that may be impacted by greenhouse gas reduction policies. It found that Collie's greenhouse gas emissions, while significant, are dwarfed by projected emissions from a proposed massive expansion of the State's LNG export industry, which will have significant economic, environmental and social impacts for Pilbara and Kimberley communities and is also based on a finite and dwindling resource. Chapter 8 found that resilience assessment could be a useful tool for those communities.

9.2 Recommended further research

This thesis finds there is a role for either academia and by policymakers at a local level to conduct resilience assessment on many Western Australian communities facing proposed expansion of greenhouse gas-intense, finite resource-based industries in their vicinity, such as in the mid-west, Pilbara and Kimberley. It is likely that following such assessments, further research will be needed to develop transition strategies for each community, including measures to improve attributes of adaptive capacity such as economic and social diversity, awareness and social capital. One of the outcomes of this resilience assessment of Collie is to show there is need to develop a transition strategy for Collie.

This case study also examined, as a secondary line of inquiry, the presence of perverse resilience and found evidence that this exists in many forms at both a local level in

Collie, as well as, in particular, at State energy policy level, including within government-owned energy utilities, the media and the State's senior bureaucracy. The alarming trajectory for Western Australia's greenhouse gas emissions and the fact that more than half of the State's greenhouse gas emissions come from energy industries, calls for further research to examine the perverse resilience that pervades energy policy in Western Australia.

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Appendix 1

Questions to key informants:

1. What concerns do you have, if any, for the future of Collie including society, economy or the environment?
2. What limits, if any, are you aware of, regards how long coalmining can continue in the Collie area?
3. In your view, what are the main benefits of the coal industry to Collie, including benefits to the economy, environment or society of Collie?
4. In your view, what are the main negative impacts from the coal industry on Collie, including economy, environment or society of Collie?
5. What groups or individuals are you aware of that are showing leadership o innovation regards planning for Collie's future?
6. Given ongoing public debate about the need for a low-carbon future, in your view, how vulnerable is Collie given the number of people employed in the local coal industry?

Appendix 2

Projected new greenhouse gas emissions, Western Australia

Liquified natural gas projects (pending approval or approved)

Project	**Proponent**	**Projected ghg emissions (mtpa)**	**Planned first production**
Gorgon (Barrow Island)	Chevron, Exxon Mobil, Shell	5.4–8.8 Range depends on whether geo-sequestration occurs [19]	2014
Pluto (Burrup Peninsula)	Woodside	1.8–4.1[20] Based on 4.8mtpa and 12mtpa LNG production	2011 2016
Browse Basin (James Price Point)	Woodside	7.1–32 Based 11mtpa and 50mtpa of LNG production.[21]	2011 (11mtpa production) 2015 (50mtpa production)[22]

[19] P30 http://www.epa.wa.gov.au/docs/2937_Rep1323GorgonRevPer30409.pdf and P31 http://www.gorgon.com.au/review/FromClient/Gorgon_Revised_Proposal_PER_Final_Main_Report_20080909.pdf.

[20] P31 of http://www.epa.wa.gov.au/docs/2533_Bull1259.pdf

[21] P81-82 http://www.dsd.wa.gov.au/documents/NEW_Browse_LNG_Precinct_-_Public_Information_Booklet.pdf

Wheatstone (Ashburton North – south of Onslow)	Chevron	10–15 Once at 25mtpa of LNG production[23]	2016
Prelude (Floating offshore)	Shell	2.3[24]	2016
PROPOSED TOTAL ANNUAL EMISSIONS BY 2016 FROM NEW LNG (assuming Gorgon part geo-sequesters)		**58.9**	

Coal projects (pending approval or approved)

Project	**Proponent**	**Projected ghgs emissions (mtpa)**	**Planned first production**
Urea plant (Collie)	Perdaman Chemicals and Fertilizers	3.4[25]	2013[26]
Bluewaters 3 power station (Collie)	Griffin Energy	1.5[27]	2013[28]
Bluewaters 4	Griffin Energy	1.5	2015

[22] P93 http://www.dsd.wa.gov.au/documents/NEW_Browse_LNG_Precinct_-_Public_Information_Booklet.pdf

[23] P5: http://www.epa.wa.gov.au/docs/3008_WS0-0000-HES-RPT-CVX-000-00003-00Rev3_2nd.pdf

[24] P169 http://www-static.shell.com/static/aus/downloads/about_shell/prelude/completeeisdoclowres.pdf

[25] P25 of http://www.epa.wa.gov.au/docs/1358/Rep1358PerdamanPER10510.pdf

[26] http://www.perdaman.com.au/our-operations/collie-urea-manufacturing/project-timeline.aspx

[27] P6 of http://www.epa.wa.gov.au/docs/1349/Rep1349Blue3_4PER8310.pdf

[28] http://www.griffinenergy.com.au/default.aspx?MenuID=310

power station (Collie)			
Muja A-B power station refurbishment (Collie)	Verve	1.3[29]	2012/13
Coolimba power station (Eneabba)	Aviva	4.2[30]	2013
PROPOSED TOTAL ANNUAL EMISSIONS BY 2016 FROM NEW COAL		**11.9**	

Iron ore (pending approval or approved)

Project	**Proponent**	**Projected ghg emissions (mtpa)**	**Planned first production**
Balmoral South (Karratha)	Mineralogy	2.7[31]	2012[32]
Karara/Blue Hills (Morawa/Perenjori)	Gindalbie/Ansteel	1[33]	2011

[29] http://www.parliament.wa.gov.au/hansard%5Chansard.nsf/0/9976121b1cdc74a8482576e000151958/$FILE/C38%20S1%2020100302%20p357b-357b.pdf

[30] http://www.coolimbapower.com.au/images/stories/pdf/PER/8_-_Pollution_Impacts_v4.pdf

[31] P(iii); P33 http://www.epa.wa.gov.au/docs/3043_Rep1340BalSPER51009.pdf

[32] P6 of http://www.epa.wa.gov.au/docs/3043_Rep1340BalSPER51009.pdf

[33] P39 of http://www.gindalbie.com.au/PER%20chapter%207.pdf?id=175